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"TREATMENT AND DISPOSAL OF SUPERPHOSPHATE PLANT EFFLUENTS"

by R. Donald, B.Sc., A.R.I.C.

A D D E N D U M

Page 8. Delete final paragraph beginning "An interesting patented scrubber is the menin type .... The space requirement of the unit appears small" and substitute following:- "An interesting patented scrubber is the Pease-Antony cyclonic scrubber. This is often used in conjunction with the Pease-Antony venturi scrubber for dust removal but in the case of superphosphate effluent gases, it is usually used alone. It consists of a vertical cylindrical cyclonic chamber in which the gas enters tangentially at the bottom and travels upwards in a spiral path. Water is introduced into the rotating gas as a spray from an axially-located manifold in the lower part of the chamber. The fine spray droplets are caught in the gas stream and are swept by centrifugal force to the wall of the cylinder where it is collected and runs down and out of the bottom of the unit. The unit can be constructed in rubber-lined steel and is relatively low in cost. The pressure drop is low, ranging from 2 to 4 inches water gauge. The water consumption is also low and of the order of 5 to 10 gallons per 1,000 cubic feet of gas. The space requirement of the unit is small."

Page 3. Paragraph 3. After the words "efficiency of elimination exceeds 99%" Add "(0.1 grain SO_3 per cubic foot is equivalent to 0.23 gramme SO_3 per cubic metre)".

Page 6. Table III. Final column heading to read "Gallons per 1000 cubic foot" and not "Gall./min./1000 c.f.m.".

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TREATMENT AND DISPOSAL OF SUPERPHOSPHATE PLANT EFFLUENTS

By R. Donald, B.Sc., A.R.I.C.

We all wish to live in a clean healthy atmosphere and apart from legal responsibilities, we have a common moral duty to contribute to the best of our ability and to the utmost limits of practicability towards establishing and maintaining this end.

Industrialists have an added responsibility as a result of the problems created by essential manufacturing processes.

In the fertiliser industry, our chief concern in this connection arises from the gaseous and liquid effluents deriving from the manufacture of superphosphate.

This paper will deal with the treatment and disposal of these by-product effluents.

GASEOUS EFFLUENTS.

Let us consider, firstly, the problem of gaseous effluents.

Source of Effluent

In the manufacture of superphosphate, a number of reactions take place which give rise to the evolution of gases, e.g. liberation of carbon dioxide, but the only gas evolved in such quantity as to create a possible health hazard is silicon tetrafluoride. When sulphuric acid reacts on natural phosphate rocks, fluorine is evolved as gaseous silicon tetrafluoride. This fluoride arises from the reaction of hydrogen fluoride on the silica in the phosphate rock.

$$2\ Ca_5F(PO_4)_3 + 7\ H_2SO_4 + aq = 3\ Ca(H_2PO_4)_2 + 7\ CaSO_4 + 2\ HF + aq$$

$$4\ HF + SiO_2 = SiF_4 + 2\ H_2O$$

Given time, the silicon tetrafluoride would be hydrolysed by the water present in the reaction mixture but much of it is swept away from the reaction zone by the rush of carbon dioxide simultaneously liberated. Some hydrolysis does take place in the flues before the gases reach the wash towers.

Amount of Fluorine Volatilised

Moroccan phosphate rock contains about 4.2% F. and 1.6% SiO_2. This silica content is insufficient to supply all the silicon necessary for all the fluorine formed silicon tetrafluoride. However, only part of the fluorine content of phosphate rocks is thus liberated, the proportion depending upon a number of factors, including type of rock, strength of acid, temperature of reaction mixture etc. It has been our experience with Moroccan rock that the average amount of fluorine volatilised is about 25% of the total. In the case of Kola apatite containing 40% P205, 1.6% SiO_2, 3.3% F, the fluorine volatilisation was 18.5%. With Florida land pebble, Jacob et al (1942) reported that the fluorine volatilised in normal superphosphate manufacture ranged from 16.5% to 31.2% with an average of 21.4% whereas with Tennessee brown rock, the range was from 28.1% to 42.1%, with an average of 35.5%. Jacob et al concluded from an analysis of the results reported that the tendency of fluorine to volatilise decreased with increase in the grade of rock but that from the results they did not find any readily apparent correlation between the fluorine volatilisation and any of the manufacturing conditions. However, it is generally accepted that the higher the temperature of the reaction mixture and the higher the acid strength, the greater the fluorine volatilisation.

It is of interest to note that in the manufacture of triple superphosphate by the Dorrco process, it has been reported that approximately 5-10% of the total fluorine present in the acid and rock is removed in the reaction stage and a further 30-40% removed during drying. (Porter & Frisken, 1953.)

Hazards

The hazards from elemental fluorine and certain fluorine compounds, including silicofluorides, are well-known but there appears to have been little work carried out on the toxicity of silicon tetrafluoride to human beings. Most superphosphate factories have one or two older employees who have long been exposed to superphosphate gases without any apparent injury. Indeed, in some of our works, we have still a few employees who were employed in the old hand dens where concentrations of gas were exceedingly high. The effluent gases, however, even if not highly toxic, are undoubtedly offensive and harmful to vegetation and should be eliminated or at least the concentration reduced to a minimal level before they are released to atmosphere.

Legislation

In Britain manufacturers have a legal responsibility not to discharge high concentrations of offensive gases to atmosphere. The relevant law is the Alkali etc., Works Regulation Act, 1906, which consolidates and extends previous similar Acts, the first of which was passed in 1863. It applies to Scotland as well as England.

This Act, which includes a schedule of chemical processes and a list of noxious or offensive gases, controls the emission of fluorine compounds from superphosphate works. The essence of the Act lies in the requirements that (1) scheduled processes must be registered annually, (2) as a prior condition in the case of a first registration, the scheduled process must be equipped to the satisfaction of the Chief Inspector with the "best practicable means for preventing the escape of noxious or offensive gases" to atmosphere and for rendering such gases "harmless and inoffensive", (3) the "best practicable means" must thereafter be maintained in good and efficient working order and must be operated continuously, and (4) in the case of certain processes, upper limits are specified for the concentration of total acidity in effluent gases which may be discharged to the atmosphere.

Provision is made for the setting up and maintenance of an Inspectorate to administer the Act, and Regulations are included relating to the registration and inspection of works, general procedure, penalties etc. The Chief Inspectors are required to make an Annual Report to be laid before Parliament, relating to the work of the Inspectorate.

In the case of superphosphate gases, the acidity and not the fluorine concentration is measured. No upper limits are specified but in the 1950 Annual Report, the Chief Inspector stated that the standard which he recognised as complying with "best practicable means" presumes that either the acidity of the escape is less than 0.1 grain (calculated at SO_3) per cubic foot or that the efficiency of elimination exceeds 99%.

Many of the present scrubbing plants in the U.K. were designed for a much lower load than they are now carrying and consequently are not able to work to these limits but they must be borne in mind when new plants are installed or old plants overhauled.

Legislation in other countries is varied. For example, German Law on the subject appears to follow the same general lines as British Law. The employment of best practicable means is, in theory, required but a few years ago there appeared to be weakness in enforcement since few, if any, official inspections or tests were made. Greater control, however, was exercised over the siting of new works and local officials appeared to possess substantially wider powers than in Britain (B.I.O.S. Report No. 690).

The U.K. Productivity Team on Fertilisers which visited the U.S.A. in 1949 reported that there was an absence of any general law forbidding the emission of noxious gases or fumes. Local laws did, however, exist in some parts of the country.

Even in countries where the emission of gaseous effluents is not subject to special legislative control, these effluents may cause offence to neighbours and may give rise to action at Common Law.

Average Acidities of Gaseous Effluents.

The effect of the Alkali, etc. Act in reducing and maintaining at a low level the acidity of gaseous effluents from superphosphate plants is seen in Table I.

Table I

Acidities of Effluent Gases from Superphosphate Plants
(Figures till 1935 from Parrish & Ogilvie (1946) and from 1936-1951 from Annual Reports of Chief Alkali Inspector.)

Years	Average Acidity (as grains SO_3/cub.ft.)	
	England	Scotland
Up to 1890	.46	
1891 - 1900	.37	
1901 - 1910	.23	
1911 - 1920	.12	
1921 - 1930	.07	
1931 - 1938	.05	.05
1939 - 1945	.11	.10
1946 - 1951	.11	.13

The reason for the increase in acidity since 1939 is that the very considerable increase in superphosphate production has been achieved mainly on existing superphosphate plants with the result that the scrubbing towers have become heavily overburdened.

Method of Testing Effluent Gases

It is appropriate at this point to discuss the method of measuring the acidity of the effluent gases.

Known volumes of gas are drawn into Fletcher's Bellows containing water and a little neutralised calcium chloride solution. The bellows containing the gas and liquid are well shaken and the liquid emptied out and titrated with standard caustic soda solution. The practice of adding calcium chloride to the absorption liquid before titration was introduced by Dr. Affleck, H.M. Alkali Inspector, in 1901. He showed that the solution before titration contains essentially hydrofluosilicic acid and that the action of alkali on that acid proceeds in two stages:-

(1) $H_2SiF_6 + 2\ NaOH = Na_2SiF_6 + 2\ H_2O$

(2) $Na_2SiF_6 + 4\ NaOH = 6\ NaF + Si(OH)_4$

In the case of straight titration with caustic soda, using methyl orange as indicator, the end-point is indefinite and recurrent due to the fact that no precise colour change occurs because the silico-fluoride formed has an acid reaction while sodium fluoride has an alkaline reaction. Stage (1) requires only a third of the alkali needed to complete the whole neutralisation and in calculating the acidity, the total volume used for titration, is, therefore, often divided by three.

The end point of stage (1) can be satisfactorily determined if sufficient alcohol is added to precipitate the silicofluoride as it is formed. If alcohol be replaced by calcium chloride solution, the titration can be carried to the end of stage (2) because calcium silicofluoride is soluble and calcium fluoride soluble under the conditions of titration (Damon, 1953).

(3) $H_2SiF_6 + 6\ NaOH + 3\ CaCl_2 = 3\ CaF_2 + 6\ NaCl + Si(OH)_4$.

In Scotland, it is not the practice of the Chief Alkali Inspector to divide by three the total volume used for titration in the presence of calcium chloride.

Types of Scrubbers

The one feature common to all the types of equipment used to remove silicon tetrafluoride from the effluent gases is that they all rely on the hydrolysis of this compound by water according to the following reaction:-

(4) $3\ SiF_4 + 2\ H_2O = SiO_2 + 2\ H_2SiF_6$.

This reaction is carried out at cool temperature to avoid the alternative reaction:-

(5) $SiF_4 + 2\ H_2O = SiO_2 + 4\ HF - 25.8$ cals.

This latter reaction, however, can only occur when the temperature is high enough to prevent the secondary formation of hydrofluosilicic acid which develops sufficient heat to compensate for this absorption (Mellor, 1947).

(a) Spray Tower Systems

The oldest and still most commonly used type of absorption equipment is the simple spray tower system. With an adequate supply of water and sufficient delay period for the gases, this system is remarkably efficient in producing an inoffensive effluent. Usually a number of void towers are employed and the more efficient systems include a tower provided with horizontally-placed baffles so as to cause the gas to pursue a tortuous path. This provides a delay period for the gases in order to give sufficient time for efficient hydrolysis of the silicon tetrafluoride and also serves to provide settling trays for the precipitated silica (cf. reaction (4)). This delay period has long been advocated in this country by H.M. Alkali Inspectors. Because of the deposition of silica, it is not possible to use many of the conventional type of absorption equipment, e.g. packed towers, bubbling trays etc.

Before considering the detail design of these towers, it is of interest to note some characteristics of a group of spray tower absorption plants for which operational details were available. Table II gives some physical details and Table III records the absorption efficiency and water consumption.

Table II

Details of Some Vertical Spray-Towers

Plant	Type of Den	Total Volume of Towers	Length of Travel of Gas	Approx. Gas Volume	Retention time of gas in towers	Av. Velocity of gas
		Cub.Ft	Ft.	Cub.ft/min	Sec.	Ft./Sec.
1	Continuous 6½ t.p.h.	2600	260	10,000	15.6	17
2	Batch 30 t.p.h.	1550	180	10,000	9.3	19
3	Batch 30 t.p.h.	1650	126	8,800	11.2	11
4	Batch 30 t.p.h.	2400	250	6,000	23.9	10
5	Batch 30 t.p.h.	2550	180	7,000	22.0	8
6	Continuous 8 t.p.h. (and/or Batch 30 t.p.h.	5400	288	24,000	13.5	21

Notes: 1. The tonnage per hour figures for the batch dens are in terms of the tonnage rate only during batching as this is the period when gases are mainly evolved.

2. The spray towers at plant No. 6 are common to two superphosphate dens.

Table III

Efficiency and Water Consumption of Spray Towers

Plant	Type of Den	Average Acidity (as grains SO_3/cub.ft.)		Absorption Efficiency	Water Consumption	
		Inlet Gas	Outlet Gas		Gallons/hr.	Gall./min./1000 c.f.m.
1	Continuous 6½ t.p.h.	3.49	free	100.0	1,150	1.9
2	Batch 30 t.p.h.	6.92	0.12	98.3	1,600	2.7
3	Batch 30 t.p.h.	9.26	0.13	98.4	560	1.1
4	Batch 30 t.p.h.	4.24	0.06	98.6	600	1.7
5	Batch 30 t.p.h.	1.26	0.12	90.5	500	1.2
6	Continuous 8 t.p.h.	2.4	0.04	98.4	1,000	0.7
6	Batch 30 t.p.h.	11.5	0.05	99.6	1,000	0.7

These figures are believed to be fairly representative of typical spray towers but in the case of the average acidities, the total volume used for the titration was not divided by three and consequently the acidities appear high.

Although the data shows some inconsistencies, the figures are generally of the same order. This, together with our experience of operation and considering the recommendations of the Alkali Inspector, enables some general principles for the construction of towers to be enunciated.

The four essentials are (1) the gas must be cooled; (2) the gas must be thoroughly wetted; (3) the gas must be given a delay period and (4) this must be followed by a series of towers to absorb the acid products of decomposition. We have found that these conditions are efficiently met by a unit having three vertical void spray towers, followed by a large vertical tower of rectangular section in which are placed a number of horizontal baffles ensuring that the gas follows a long tortuous path of about 100 ft. This tower has no water sprays and is followed by a further three void spray towers. The gases enter the top of the first tower, travel downwards and enter the bottom of the second tower, travel up and enter the top of the third tower and so on. Fig. 1. is a diagrammatic sketch of a typical layout.

The total volume of the unit should be chosed so that the gases are delayed by not less than 8 secs. and preferably longer. Most of this delay can occur in the dry tower, provided the gases are well cooled and wetted in the preliminary spray towers.

The spray towers can be of either square or round section. Many materials of construction have been successfully used, including brickwork, either acid-resistant or common brick (preferably hard burnt), rubber-lined steel and woodwork (preferably pressure creosoted pitch pine).

With regard to the sprays, we have tried several types but found the most successful to be of the hollow cone type, delivering about 50 gallons per hour at 80 pounds per square inch pressure and constructed in hard rubber with acid resistant-nozzles and discs. These are inexpensive and are readily cleaned. The sprays are connected to a short piece of flexible rubber hose which permits them to be easily withdrawn for inspection or replacement. Nozzles should be inspected frequently (at least daily) for plugging. Chokages are not frequent but when they do occur, they can seriously impair performance of the towers.

It has been stated that the positioning of the sprays is critical (Annual Reports, H.M. Alkali Inspector, 1950) but in our experience, we have found that provided an adequate supply of water is maintained and the sprays are kept clean, the positioning appears to have a minor effect. Some towers have all the sprays in the top, some towers have all the sprays in the sides and some operate on a combination of these. We can attribute little, if any, difference in performance to this variation. It is of interest that it has been reported that a single large spray is practically as good as a number of small sprays handling a similar quantity of liquid (Schofield, 1952).

The water used in the sprays should be from a clean source or filtered. We have carried out some tests using a proportion of filtered sea water to augment the fresh water supply. No trouble due to build up of sodium silicofluoride was experienced but another report (Schofield, 1952) on the use of saline bore-hole water alone indicated considerable difficulties due to the deposition of sodium silicofluoride as a hard marble-like mass.

The towers are usually cleared out of solids once per week by hosing down.

Another important point is the siting of the fan. The best position is at the outlet of the last tower. In this way the entire system is maintained under suction and the fan has only to deal with clean gas. A common fan construction is Tufnol blades fitted to mild steel spider arms but our most trouble-free fan has a large impeller of rubber-covered steel running in a concrete casing lined with an acid-resistant carbon cement. The casing is fitted with a wooden cover. This fan has been running several years without any renewals and with little attention. The fans are usually run at a comparatively slow speed of about 400 r.p.m.

The fan capacity should be sufficient to maintain a small but definite negative pressure at the superphosphate mixer and throughout the scrubber system.

With batch dens it is common practice when "cutting-out" to pass the gases through the towers without the water sprays being turned on as it is mainly steam which is evolved during the period.

The gas from the fan should discharge into a chimney. This should preferably by a high hot chimney to give good dispersion. A chimney or not less than 100 feet high is recommended.

This water spray treatment removes most of the acidic constituents of the effluent but with some phosphate rocks the residual gases have a strong organic smell. This is readily removed, if necessary, by chlorination in the chimney.

Disadvantages of Spray Towers.

Although the simple spray tower type of equipment efficiently fulfils the function of rendering the effluent innocuous, it suffers from the disadvantages that it is bulky, it requires a lot of water and it is not suitable for the economic recovery of the by-product fluorides. Many types of equipment have been proposed to overcome one or all of these disadvantages. We will now consider a few of these.

(b) Alternative Types of Equipment

Perhaps the simplest method of adapting the spray tower system for saving water and building up a concentrated solution of hydrogen silicofluoride is to recycle the liquor through the sprays. This, however, introduces many difficulties due to blocking of the sprays. A device to overcome this is the Lutyens scrubber. The sump is maintained full of liquor and at the bottom of each chamber or tower is located a square sectioned wooden roller, on a steel shaft, to which are attached wooden throwers. These pick up and spray into the gases, liquor which falls back into the bottom of the scrubber. Alternate rollers are driven in opposite directions so that the spray is projected against the flow of gases in the towers.

A very compact and efficient unit is that developed in Germany and described in B.I.O.S. Report No. 1743 (1946). This consists of two rectangular rubber-lined steel tanks, each of 25 tons water capacity but containing only 10 tons water. The gases are drawn into the tanks by means of a duct connection in the top and pass through the two tanks in series. The path by which the gases travel through the tanks is determined by internal perforated baffle plates which constrain the gases to pass through spray zones but not under the water level. Spray is generated in each tank by means of a conical spinner, suspended from the tank top and revolved at 1,000 r.p.m. The cone is perforated at its broad upper end by a number of holes and fitted with impeller blades at the lower narrow end which is submerged under water level. Water is drawn up inside the cone and discharged through the perforations at the top in the form of a spray. Apart from a tendency for the holes in the spinner to choke with silicic acid, which tendency has been overcome by increasing the diameter of the holes, the unit was reported in 1946 as giving little trouble. The gases pass through the tanks until the liquor reaches the desired concentration. The efficiency of fluorine recovery was reported as 90%

An interesting patented scrubber is the Menin type made by Roncuzzi Guido, Ravenna, Italy. This consists of towers built up from four flanged steel rings, 3½ feet diameter. Between the flanges are placed acid-resistant rubber inserts. The rings are coated with acid-resistant material. Between each of the rings composing the washing cylinder are placed a series of fixed plates. Down through the centre of the cylinder and fixed plates is passed a vertical axle carrying a number of specially designed plates and driven by a small motor. The water or liquor enters at the top of the cylinder through a number of small tubes and falls on to the top moving plant which throws the liquid outwards on to the first fixed plate. This in turn directs the liquid on to the second moving plate and so on down the cylinder. Before going to atmosphere, the gases and spray are drawn by fan through a cyclone separator. For a 10 ton per hour plant, the gas volume is 2,400 c.f.m. with a water requirement of 1,056 gallons per hour or 7.3 gallons per minute per 1,000 c.f.m. of gas. The space requirement of the unit appears small.

Another patented scrubber which occupies little space and which appears to be gaining popularity in the U.S.A., is that made by Schutte & Koerting, Philadelphia, In this scrubber, the water serves a double function; (1) by injection it is used to create a pressure drop in a venturi, thus eliminating the need for a fan and (2) it absorbs the gases by mixing and contact. The water under pressure enters the top of the vertical venturi (Fig. 2(b)) through a single large spray nozzle. The injection of the water produces a pressure drop dependent on the volume and pressure of the water. Discharge from the scrubber is made into a box, or tank separator, wherein non-condensible, washed gases are separated from the liquid and subsequently passed to atmosphere. A.B. Pettit (1952) described a practical installation in which the Schutte & Koerting fume scrubber is constructed in steel plate with cast iron nozzle assembly. The water nozzle opening is 30 cm. diameter and delivers 250 gallons per minute at 60 lb per square inch pressure. The whole S. & K. scrubber unit is lined with Neoprene and is mounted vertically. The gas from the venturi discharges into a large covered concrete sump. Twenty spray nozzles are mounted in the top of the sump and four spray nozzles in the foot of the discharge stack. There is a series of baffles in the base of the stack to prevent entrainment of hydrofluosilicic acid. Also in the stack, a short distance above these, there is a two-layer bed of 1" Raschig rings fitted into a drawer which permits easy withdrawal of the bed for cleaning. Liquid is bled off from the sump to a "lime-mix" tank where make-up water and lime are added automatically. Neutralised liquor is recycled to the sprays over the sump and in the stack. 500 gallons per hour of effluent liquids and solids are drawn off from the sump to a settling pond. This unit operates with a 15 ton per hour den and the gases drawn by the S. & K. venturi are 7,500 c.f.m. The apparent average efficiency is greater than 98%. The water usages are -

	Gallons per hour	Gallons per minute per 1000 c.f.m.gas
Sprays	3,600	8.0
Schutte & Koerting Venturi	18,000	40.0
Total	21,600	48.0

In considering the high water requirement of the Schutte & Koerting venturi it must be borne in mind that this unit does not use fans such as are required by other systems. A diagrammatic sketch of the unit is given in Fig. 2.

Recovery of the Fluorine as Na_2SiF_6 or other Salts

In most cases the liquor from the scrubber is run to waste but in many plants it is further treated for recovery of silicofluoride salts which are used in industry. The principal salts which are made are those of sodium, zinc or ammonium. The preparation of these salts will not be considered in this paper.

SOLID AND LIQUID EFFLUENTS

Liquids

As a result of scrubbing the effluent gases to remove the acidic constituents, the superphosphate manufacturer is left with a liquid effluent which is highly acidic. The graph of a series of pH readings on the liquid effluent from a conventional spray tower unit attached to a batch den is shown in Fig. 3. It will be observed that the maximum acidity occurs just after the den has been filled.

Even if the liquor is used for the production of sodium silicofluoride by the conventional method of adding brine, there still remains an acidic affluent as shown by the following equation:-

(6) $H_2SiF_6 + 2 NaCl = Na_2SiF_6 + 2 HCl$

If the superphosphate works is suitably placed, these effluents can often be run out to sea but if the only outlet available is either a river or a sewer belonging to the local authorities, the manufacturer in the U.K. is faced with reducing or eliminating this acidity before discharging the effluent from his works. At present, local regulations or by-laws vary with regard to the effluent but under the new Rivers, Prevention of Pollution Acts (1951) more stringent standards are likely to be applied in respect of liquid effluents discharged into rivers or estuaries. This in turn may reflect upon the standards applied to effluents which are accepted into public authority sewers and manufacturers may require considerable expenditure to meet the more rigorous standards.

To reduce the acidity of the effluent it can be suitably diluted, either by a further supply of water or with other neutral or alkaline effluents from the works. The most satisfactory procedure is to adopt an automatic liming system. Fig. 2 shows such a system whereby the liquor is recycled. Recycling after liming, however, it not usually practised, the neutralised liquor being run straight to drain.

Solid Effluent

The precipitated silica which collects in the towers, sump or settling pond might be flushed down the sewers but where restrictions exist on the solids allowed in liquid effluents, the silica may be mixed with ashes or other dry rubbish and dumped.

Granulation

If the superphosphate is granulated, then the subsequent drying and cooling operations raise additional effluent problems. The gases from the granulation plant which are hot, wet, dust laden and slightly acidic, are first passed through cyclones to remove most of the dust burden and are then usually passed through simple wet spray towers - usually only one tower is used. This treatment is often unsatisfactory and it has recently been stated by H.M. Alkali Inspector (1951) that this fume treatment for gases from granulation plants "is a compromise in that water washing is necessary both to arrest very fine dust, which the cyclone dust arrestors of the plant cannot trap and to reduce fume which can at times be appreciable but, on the other hand, water washing cools the exit gases and saturates them with water, giving them a tendency to fall in certain atmospheric conditions." The plume so formed can be very persistent.

In a very interesting paper on the comparable problem of washing boiler flue gases, Llewellyn Rees (1952) showed that in certain weather conditions washing opposes the dispersive effect of a tall chimney and may actually increase the local pollution by bringing the gases down before effective dispersion is ensured.

This problem merits considerable attention and we are looking at it from the aspect of removing the very fine particles which pass the cyclones before they enter the spray towers. We feel that if these fine particles were arrested, washing might be proved to be unnecessary. Even if washing were continued, the plume should be more readily dispersed. Our work, however, is only in the very earliest stages.

I would like to thank the Directors of S.A.I. for permission to present this paper.

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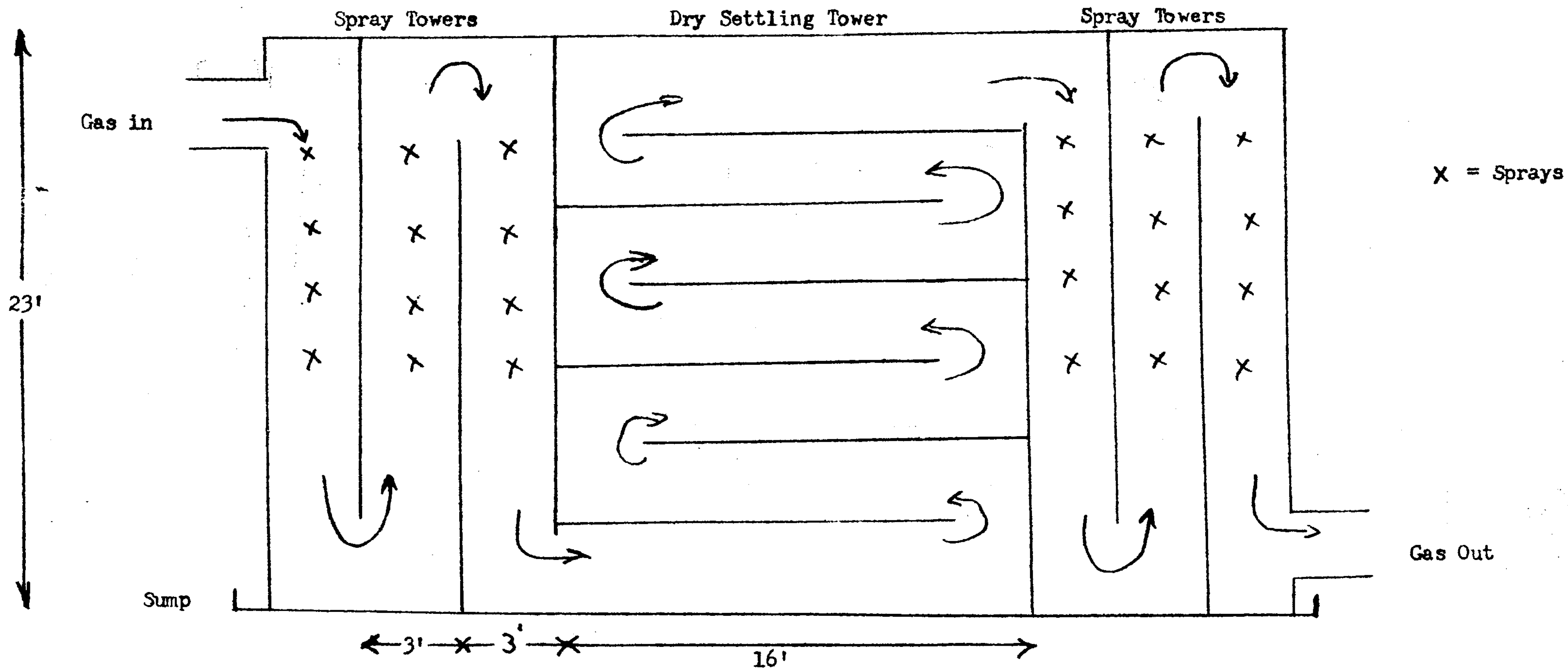
Fig. 1

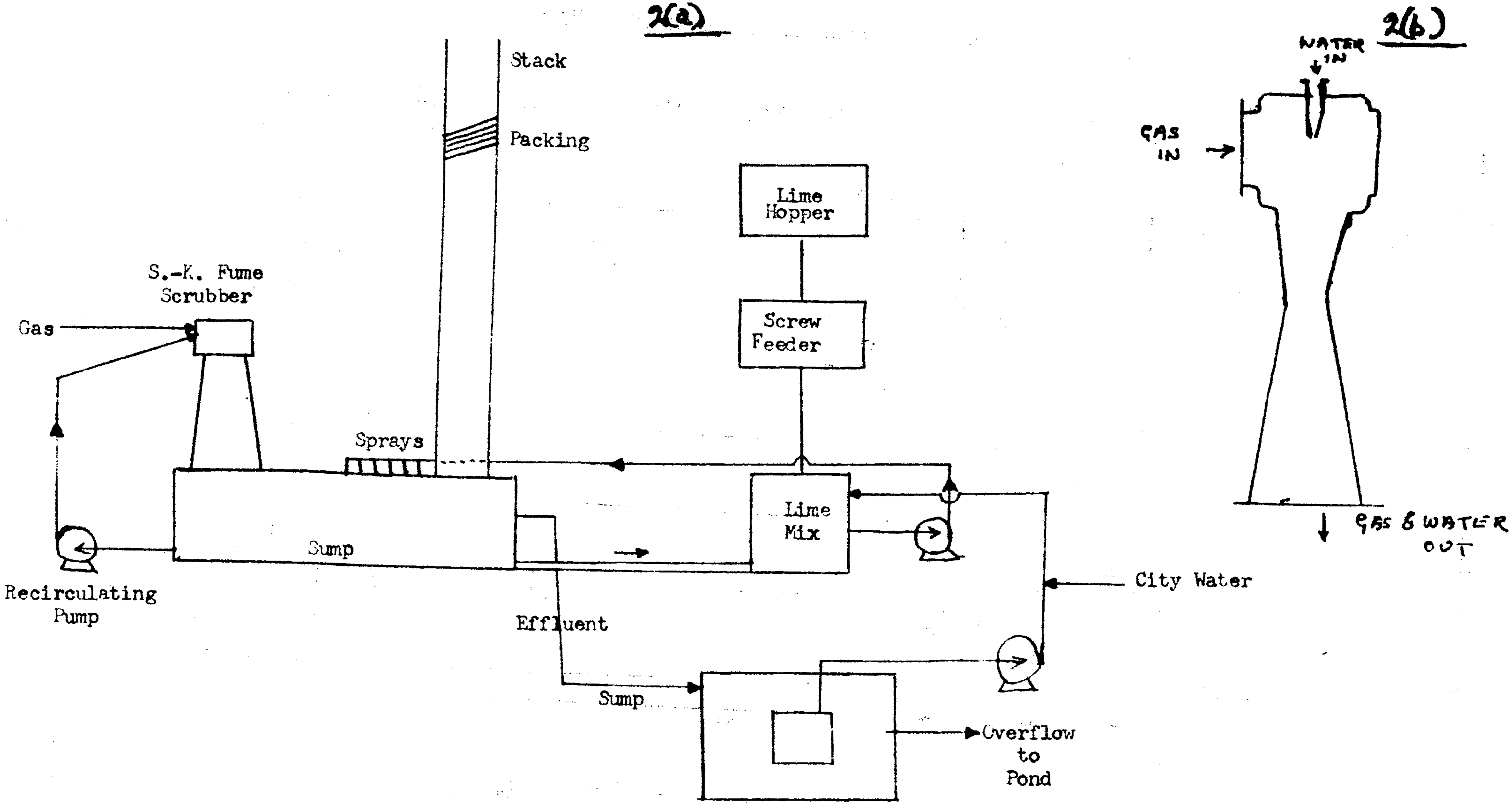
Diagram of Spray Tower Absorption System

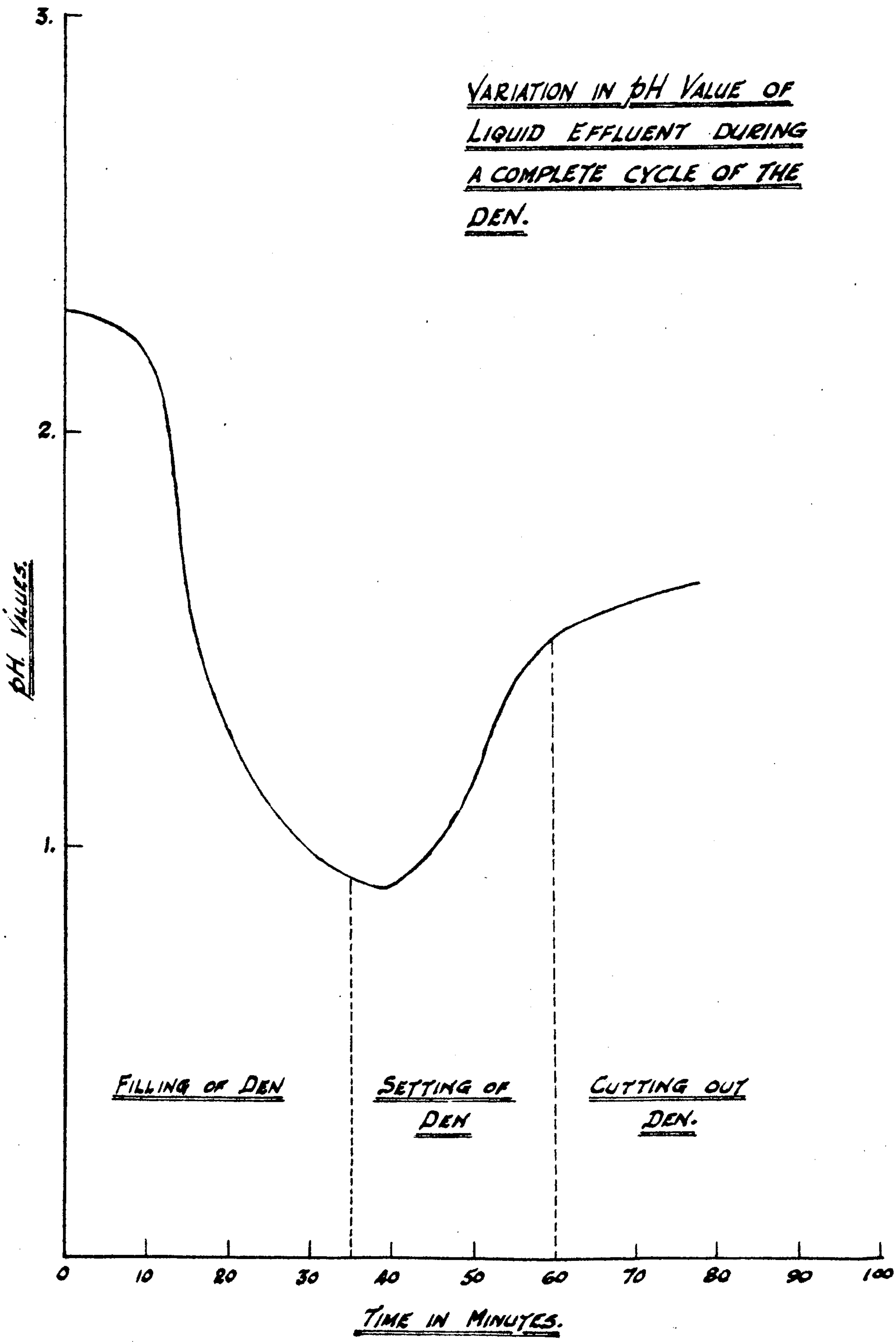


Note: The towers are not necessarily in a straight line but usually grouped with spray towers at right angles to dry settling tower

Fig. 2.

Diagram of Schutte-Koerting Scrubber with Automatic Liming





VARIATION IN pH VALUE OF LIQUID EFFLUENT DURING A COMPLETE CYCLE OF THE DEN.
3.
2.
1.
pH. VALUES.
FILLING OF DEN
SETTING OF DEN
CUTTING OUT DEN.
0
10
20
30
40
50
60
70
80
90
100
TIME IN MINUTES.

Fig. 3.