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THE USE OF GLASS FOR SULPHURIC ACID COOLERS

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(1) INTRODUCTION

At the I.S.M.A. Conference held in Cambridge in September 1953 reference was made to the use of boro-silicate glass pipes for a cooler on a sulphuric acid plant of the Petersen type. A review of operating experience on this cooler during the last six years now follows.

(2) HISTORY

The coolers were designed to deal with two main acid conditions, namely:-

(a) 45 gpm (12 M^3/hr.) of 76/80% H_2SO_4 de-nitrated acid to be cooled from 120/140°C. to 35°C.; and

(b) 375 gpm (100 M^3/hr.) of nitrous acid at the same H_2SO_4 concentration but having 1.5/3.5% HNO_3 to be cooled from 90/100°C. to 35/40°C.

The arrangement provided for gravity flow from elevated towers resulting in a maximum pressure at the base of the coolers of 17 psi (1.2 kG/cm^2).

The normal material of construction for denitrated acid on Petersen plants is lead, while for nitrous acid cast iron is usually adopted, the preference being for vertical cast pipes. At the time of construction, however, the cost of lead was very high, and vertical cast pipes were not available in the U.K. Previous experience had shown that neither lead nor cast iron were entirely satisfactory in their respective spheres, and in consequence consideration was given to the use of alternative materials.

After examination of the various alternatives, it was decided to use boro-silicate glass for all coolers. The anticipated advantages of this material were that it would be immune from chemical attack from the nitrous and denitrated acids, free from external corrosion, and unaffected by scale formation from the cooling water. It was recognised that the heat transfer co-efficient of glass is considerably less than that of new cast iron, but on the other hand glass does not suffer from a fall-off in heat transfer rate as is caused by external rust films on cast iron coolers.

The glass coolers originally installed took the form of a number of banks of serpentine pipework involving 2.7 miles (4.3 kM) of 3" (76 mm) bore, 3mm. wall thickness tubing. Each bank was four pipes wide by seventeen pipes high, as shown in fig. I. Cooling was by fresh water circulating over the coolers and through an atmospheric cooling tower.

The type of joint installed in the original cooler was as shown in fig. II, in which the flanges were in Bakelite, inserts under the flanges in asbestos, the connecting bolts in stainless steel, and the gasket in Fluon (p.t.f.e.) sheathed asbestos.

(3) OPERATING EXPERIENCE

Glass

In the first few months of plant operation serious breakage of glass pipes was experienced. This was a direct result of the form of glass construction used in which a 180° bend and two approx. 11 ft. lengths (3.1 M.) of straight pipe were made in one piece to form an elongated 'U'. As a result even slight inaccuracy in installation caused severe stressing of the bends and consequent failure. The troublesome sections of glass were completely replaced by standard straight lengths of tube and separate short U-bends at the end. Since that time breakage of glass pipes has been almost unknown. The glass pipes have not suffered in any way from internal attack from the acid or external scale formation after six years of constant operation, and apart from being slightly discoloured they are as good as on the day they were installed.

Joints

While glass breakage was successfully resolved after a short time, leaks from the pipe joints continued. The main troubles were as follows:

(a) The asbestos jointing material within the Fluon sheath was very hard and did not readily conform to variations in the face of the glass pipes.

(b) Fracture of Bakelite flanges due to water absorption.

(c) Swelling of asbestos inserts, due to absorption of water, causing flanges to fracture.

Many modifications were tried out on this basic joint design, but the troubles with leakage were not overcome. The variations tried included flanges made from a special form of Bakelite having low water absorption characteristics, cast iron flanges, and softer gasket material such as Butyl rubber or plasticised PVC enclosed in a Fluon sheath. All the variants suffered from the basic disability that the tightness of the joint was dependent upon drawing together the end faces of the glass. Where these two faces were not exactly parallel, either due to lack of uniformity of the glass itself, or by incorrect alignment between one pipe and another, the compression obtained on the gasket was not uniform across its whole face. Thus a freshly-made joint was potentially insecure and any movement of the glass-ware from expansion or contraction soon resulted in leakage. Moreover, even special Bakelite still suffered some water absorption with the result that in time the flanges cracked or increased in size with the consequent creeping together of the flanges and slackening of the joint. There was also some doubt as to whether the angle of the tapered section at the end of the tube was sufficiently steep, the standard having been changed subsequent to the manufacture of these units.

(4) NEW TUBE JOINT

As the many variations to the original form of joint showed no promise, an entirely new approach was tried, as shown in fig. III. This joint, which is the subject of British and Foreign Patent Applications, takes the form of a pliable sleeve enclosed in a metal fixing band, the latter having a number of fingers. This band is tightened by means of a clip at each end. Experiments showed that the most appropriate pliable material to resist the acid and temperature conditions was much too expensive to use for the complete sleeve. Instead only sufficient acid resisting material is used to form the seal across the adjoining sections of two pipes, while the remainder of the pliable sleeve is made in any resilient material, such as Hypalon or Butyl rubber, suitable for the operating temperature. In practice the fixing band and the clips have been made in stainless steel in order to give protection against corrosion from the cooling water, but these can be made in other materials according to the conditions.

The basic features of the new joint are:-

(a) No tensile stress is transmitted to the pipe as a result of tightening of the coupling.

(b) This absence of tensile stress is not dependent upon accuracy of pipework either in the normality of the ends or in the uniformity of mounting.

(c) As the joint remains flexible, movement from thermal or other causes neither affects the tightness of the joint nor results in significant tensile stress on the pipework. In fact any lateral movement due to end thrust on bends tends to tighten the joint.

(d) The tube joint being very much smaller in diameter than the flanged type enables coolers to be constructed with pipes at much closer pitch. Thus for a given surface area a more compact cooler is obtained, requiring less head for acid flow and offering improved conditions for water distribution.

(e) Although specially developed for glass pipework, the principles apply equally to any pipe constructed in material having a low tensile strength, e.g. stoneware, carbon, silicon iron etc.

Experimental tube joints have been in service for over twelve months without showing any defect. Of the 1900 joints already installed, only one showed a slight leak originally, and this was immediately corrected by tightening. In no other case has there been need for attention to the joints.

(5) COOLING TESTS

The feature mentioned in 4(d) above has enabled the coolers to be reconstructed at an overall height of 7 ft. (2.1 M) for 15 tubes high in comparison with 13 ft. (4 M.) for 17 tubes high necessary with the flanged joints - see fig. IV. In addition to the obvious advantage of greater accessibility, the compact arrangement gives an outstanding benefit in terms of water distribution. The considerable fall from pipe to pipe in the original form resulted in excessive splashing and very poor water contact at the lower levels. With the closer pitch between pipes ($1\frac{1}{2}$" (38 mm.) gap in comparison with $5\frac{1}{2}$" (140 mm.) previously) assisted by narrow timber strips under each pipe, a completely uniform film is provided over all pipes in the cooler.

A typical result of tests carried out on one bank of the coolers is given below:-

Acid		
	Acid flow	55 gpm (15 M^3/hr.)
	Acid velocity	1.3 fps (40 cm/sec.)
	Specific gravity	1.67
	Inlet acid temp.	71°C.
	Outlet acid temp.	42°C.
	Acid temp.difference	29°C.
Water		
	Water flow	150 gpm (41 M^3/hr.)
	Inlet water temp.	27°C.
	Outlet water temp.	34°C.
	Water temp.difference	7°C.
Heat transfer		
	Overall heat transfer co-efficient	27 CHU/sq.ft./hr./°C. (131 Kgcals/M^2/°C/hr.)

The heat transfer co-efficient obtained during the test at 27 CHUs/sq.ft./hr./°C. compares favourably with a figure of 27/28 CHUs/sq.ft./hr./°C.* commonly used for 3" bore cast iron cooler pipes at a similar acid velocity. The heat transfer co-efficient quoted for cast iron pipes is a practical design figure which allows for scale build-up on the outside.

(6) CONCLUSION

(a) The fact that the coolers on this sulphuric acid plant were reconstructed with the new couplings but using old pipes and bends which had given six years service, demonstrates that glass as a material is eminently suited to the duty of cooling sulphuric acid. It is very doubtful if any other relatively

* (131/136 Kgcals/M^2/°C/hr.)

low cost material can offer such permanent use as a heat transfer medium. In this case fresh water was used as coolant, but when sea water or contaminated waters have to be used the freedom of glassware from external corrosion or scaling is of prime importance.

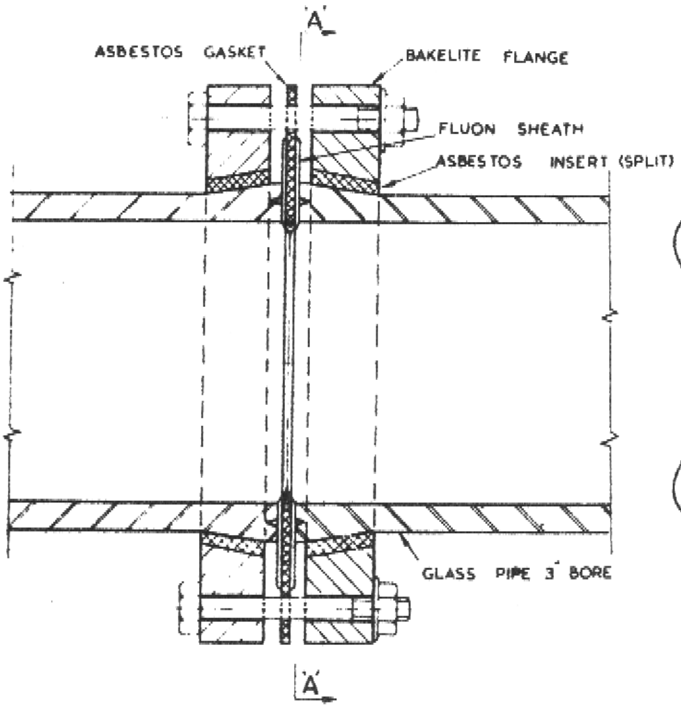
(b) The pipes remain clear internally and externally and thus the calculated heat transfer for new pipes remains true throughout use.

(c) The new tube joint enables the virtues of glass to be applied to such duties as the cooling of sulphuric acid with complete immunity from joint failures and freedom from any risk of tensile stress being transmitted to the glass from the couplings.

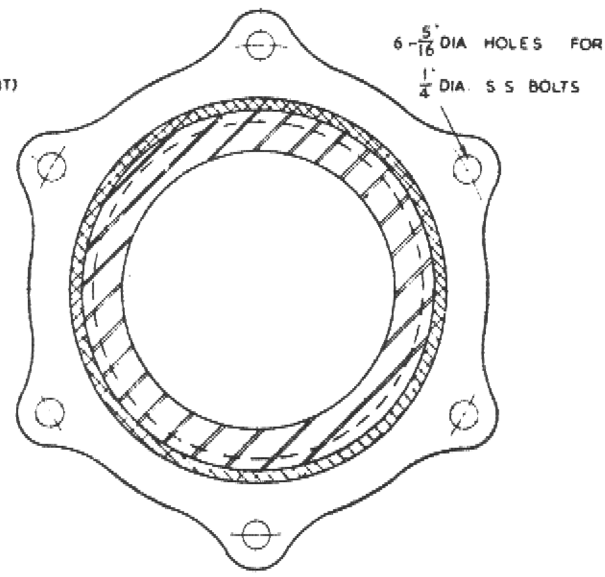
(d) The compact form which this joint permits results in a much more efficient water distribution with consequent reduction in size of cooler.

(7) ACKNOWLEDGEMENT

The authors wish to express their thanks to those colleagues who assisted in the preparation of this paper.

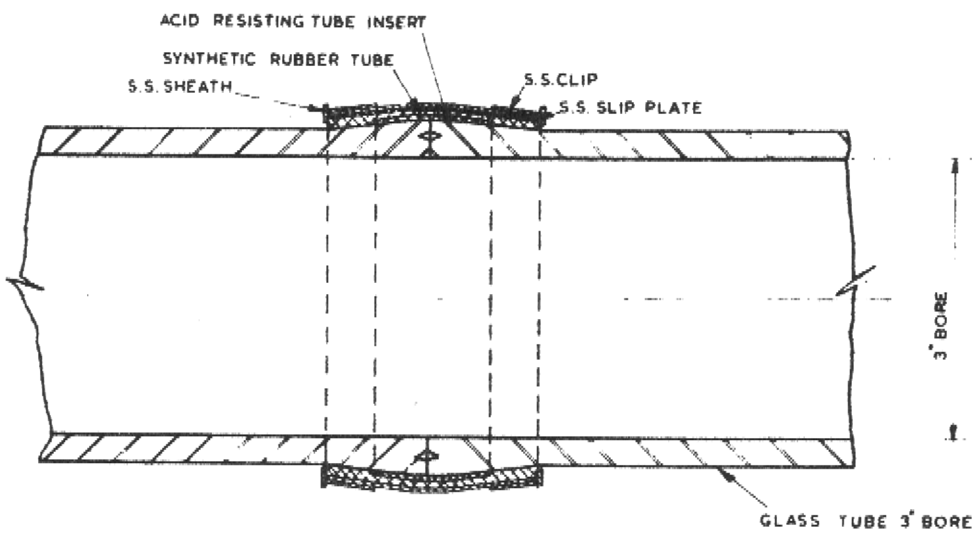


SECTION THRO' PIPE

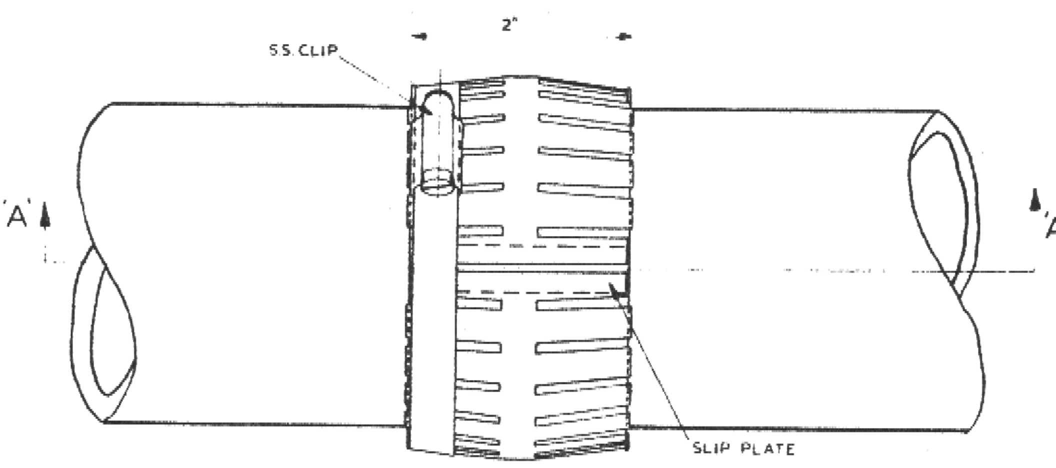


SECTION THRO' 'A A'

FIG. II



TYPICAL CROSS SECTION "A-A"



PLAN WITH ONE CLIP REMOVED

FIG III

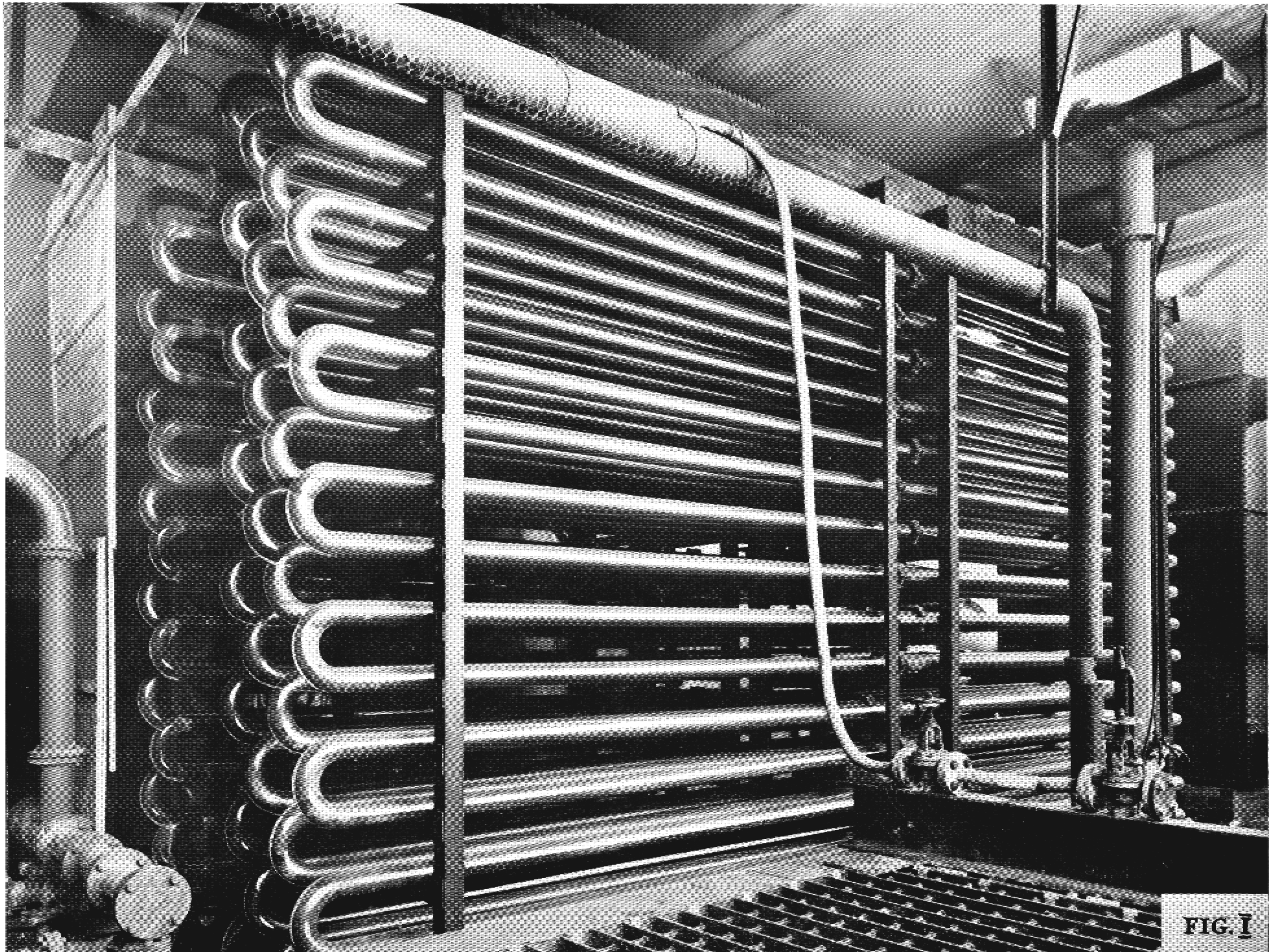


FIG. I

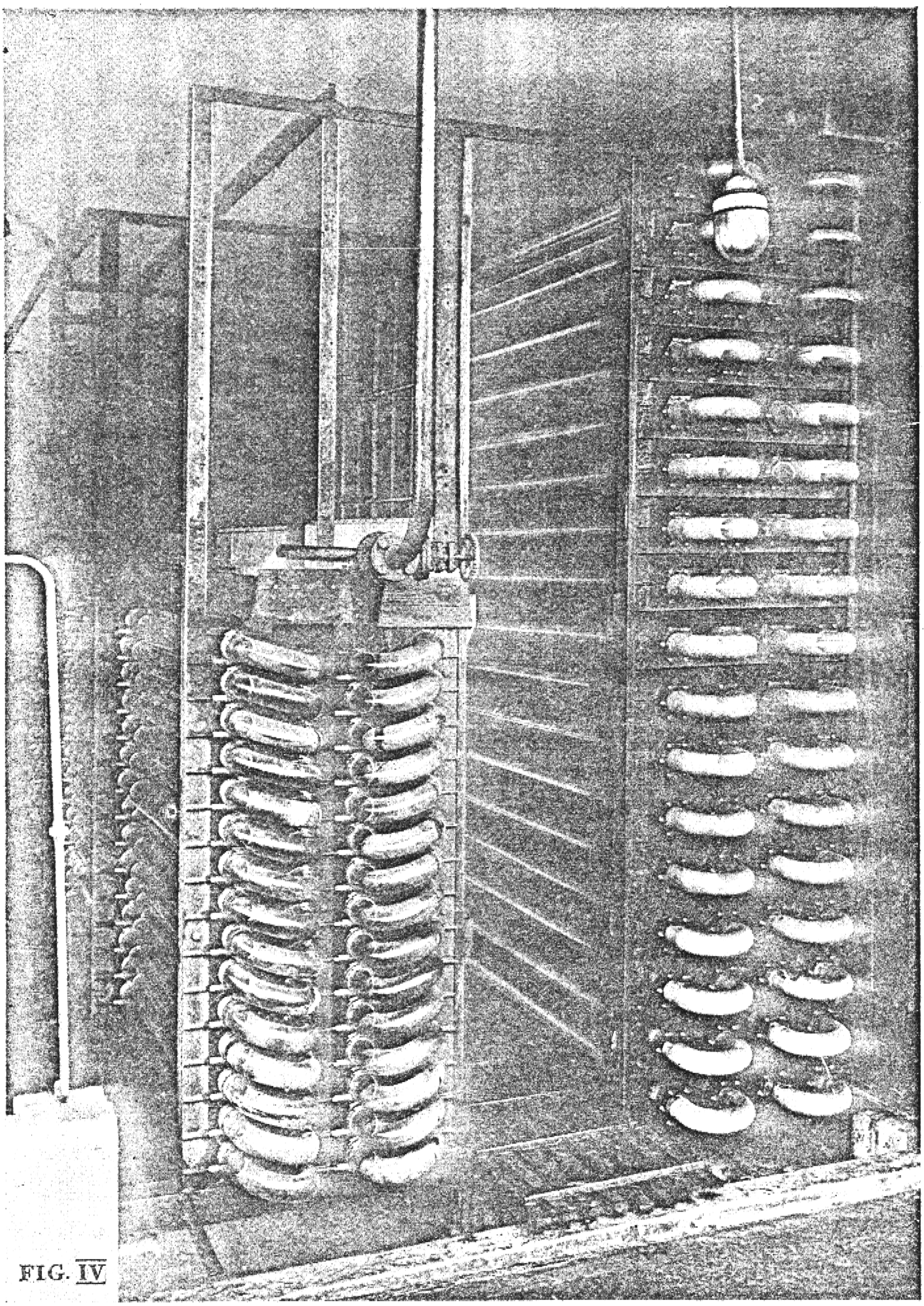


FIG. IV