ISMA* Technical Meetings

Cambridge, United Kingdom
15-17 September 1953

**In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).*

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LE 391
TECHNICAL MEETINGS 1953
Paper (a) 8

September 1953

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THE MANUFACTURE OF SUPERPHOSPHATE IN A ROTARY DEN

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INTRODUCTION

It has been generally a characteristic feature of continuous [p]ans that the superphosphate has been allowed to set in a solid [m]ass during the period of conveyance by various means between the mixer and the cutting mechanism. The system of manufacture to be described in this paper differs radically in that during the whole of the reaction period during which the superphosphate is solidifying, it is maintained in a state of slow shearing movement within its mass. In this manner, and by the aid of the disruptive forces of the gases evolved, it undergoes a continuous transition from slurry to particle form. No cutting or slicing mechanism is necessary.

MECHANICAL PRINCIPLE OF THE ROTARY DEN.

The most convenient mechanical system for maintaining the necessary condition of slow movement within the mass, has been found to be a slightly inclined, slowly rotating cylinder with a conical outlet designed to effect a suitable time of retention. The mixing of phosphate and acid is carried out continuously in a simple trough-sectioned paddle mixer, the delivery end of which is extended into the den cylinder through a fixed circular end shield fitted with a rubber seal ring.

A counter-current air stream is passed through the cylinder, the exhaust gases being carried away by means of a duct connected to the fixed shield plate at the feed end of the den. This also serves to exhaust the mixer gases.

ACID-PHOSPHATE PROPORTIONING

The normal interlocking system of proportioning gear has been found to be satisfactory, but it is quite essential that the streams of phosphate and acid are continuously and accurately related at any instant. Minor variations of, say ±1%, characteristic of continuous weighing equipment are, however, acceptable.

An automatic batch weighing machine controlled through relays by an electric interval-timer situated in the laboratory, has proved both accurate and flexible in operation. The batches are smoothed by a ribbon type worm conveyor.

Acid, of standard 77% H_2SO_4 content, is most conveniently metered by means of a wheel and bucket type feeder operating in the usual constant level tank. Dilution is carried out in a continuous diffuser, after metering the strong acid, by means of a valve and rotameter (flowmeter) in the water pipe-line under the control of the operator.

CONTROL OF PHYSICAL CONDITION.

The acid strength has an important bearing on the physical condition of the superphosphate produced. Within the range of concentration of 68% to 74% H_2SO_4, the product ranges from small granules to a remarkably dry powder containing a small production of soft nuggets up to 5 c.m. in diameter.

Whilst the control of dilution water is particularly useful where the superphosphate is to be immediately passed to a granulation process, an equally important variable is that of the rate of rotation of the den cylinder. A variable speed drive is employed, and in the unit operating at York, which has a diameter of 4 ft. 6 inches (1.37 m.), a peripheral speed range of 1.5 to 3.5 metres/min. is used. The lowest speed produces a predominantly powder like condition, whilst higher speeds produce a granular form.

Control is simple and the process very stable in operation.

CHEMICAL CHARACTERISTICS OF THE SUPERPHOSPHATE.

Owing to the continuous movement of the reacting mass, gas clearance is extremely efficient, as a result of which superphosphate can be produced with a remarkably low moisture content as it leaves the den, after no more than 30 minutes reaction time. Maturing in the heap is relatively fast, owing to the granular structure, which allows both of rapid drying out and easy re-claiming.

Typical curing time curves (figures I and II) both for superphosphate ex den and for superphosphate granulated by rotary drying immediately after the den are characteristic for the process when working on Moroccan phosphate (33.7% P_2O_5) ground to the following sieve analysis:-

Passing 100 mesh B.S.S.	91.1%
Passing 150 mesh B.S.S.	72.4%

The actual analyses of the products tested (a) within one hour of production and (b) after 14 days maturing in sealed containers, were as follows:-

	Ordinary Super.		Granular Super.	
	(a)	(b)	(a)	(b)
Sol. P_2O_5	16.87%	18.68%	18.03%	19.12%
Total P_2O_5	19.41%	19.41%	20.09%	20.09%
Free Acid as P_2O_5	6.82%	2.41%	6.00%	3.83%
Moisture	9.59%	9.59%	6.44%	6.44%
Conversion	87.00%	96.20%	90.00%	95.25%

CONSTRUCTIONAL DETAILS.

The main features of design will be apparent from figure III.

Mixer. The preferred form is a single paddle shaft, deep trough type constructed in cast iron, inclined backwards in order to achieve suitable initial reaction time. The outlet end is extended in the form of a trough conveyor protruding through the end shield into the rotary den. The working conditions are adjusted so that the slurry is retained until partially thickened. To this end the paddle shaft revolves no faster than is necessary to achieve adequate mixing. Furthermore, if the designed speed is too fast, the gases are released too quickly before the disruption stage. Cast iron paddles have given the best service in contact with the incoming sulphuric acid and ground phosphate, whilst antimony-lead alloy serves best in the later stages where the reaction is well advanced.

Rotary reaction vessel. We have found a soft rubber-lined mild steel construction gives satisfactory service. The cylinder has a plain inner surface, which carries a very slight adherence of superphosphate, which assists in insulating the cylinder against heat losses.

The design of the seal (figure IV) between the fixed end shield and the cylinder is critical to the successful operation of the process. Our final development from various experimental seals consists of a relatively thin stainless steel circular band fastened internally as a lip slightly extended beyond the end of the cylinder. The edge of the lip which must be true and slightly radiused, makes a circular sliding contact with the face of a flat rubber ring attached to the periphery of the shield plate. Sufficient pressure is applied by means of an adjustable backing plate. There is no tendency to cut the rubber face which is sufficiently lubricated by the superphosphate slurry.

COMMERCIAL ASSESSMENT OF THE PROCESS.

This den has proved itself to be well suited to the needs of a small works, and has been in successful operation at York, on a three-shift basis, for five years. Whilst this particular unit has a maximum capacity of only 3.5 tons per hour, the principle of operation is considered extensible to 10 tons per hour units, above which the pressure of the depth of superphosphate in the cylinder would limit the effectiveness of the gas disruption process.

It has been used both for the manufacture of ordinary superphosphate and for direct alignment with a granulating plant producing compounds and granular superphosphate. Owing to the readiness with which the physical condition of the fresh superphosphate can be controlled, it has special possibilities for direct production of granular superphosphate of sufficiently low moisture content without using a rotary dryer.

FIG I

CURING TIME CURVE - WATER SOLUBLE P_2O_5

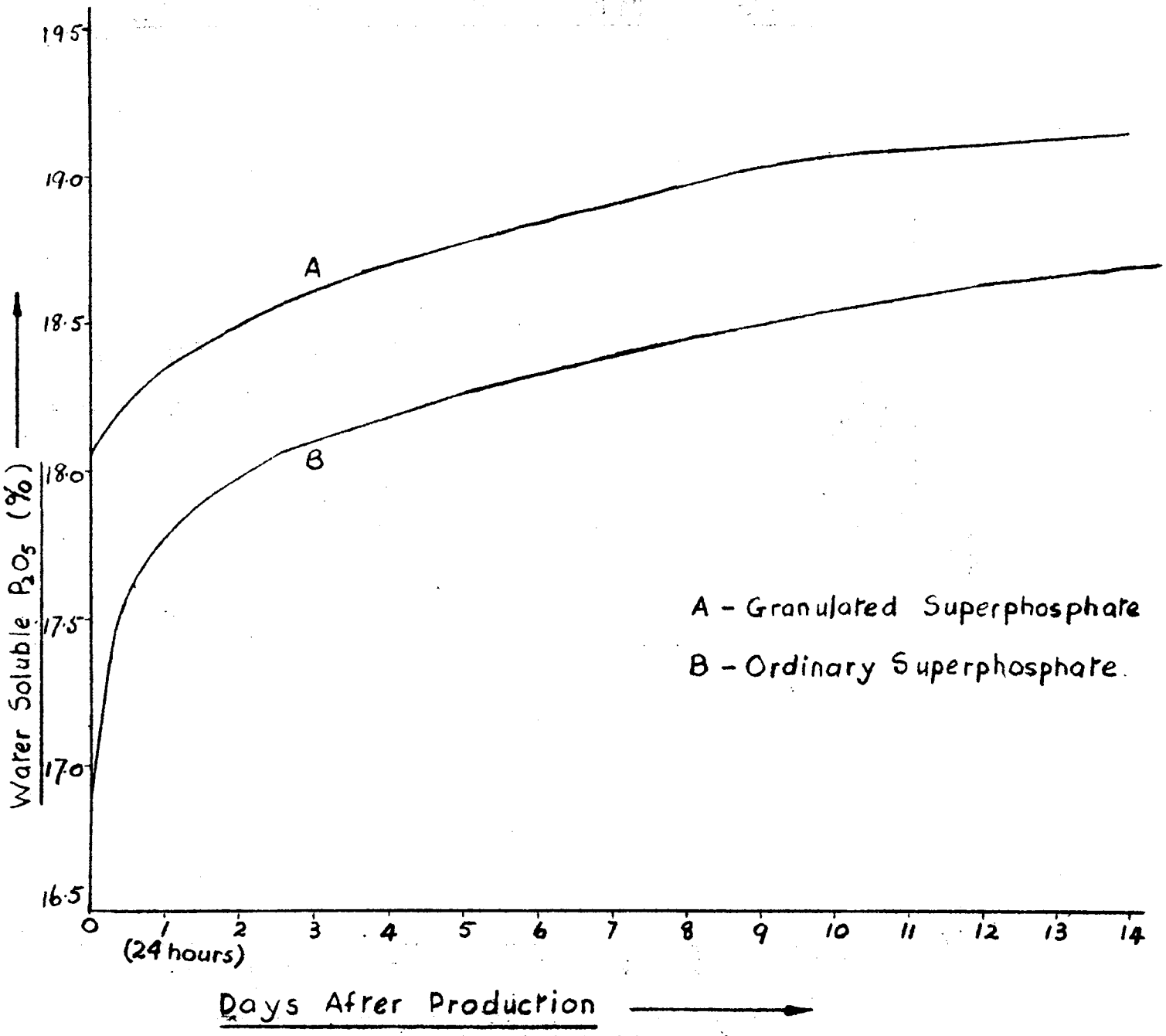
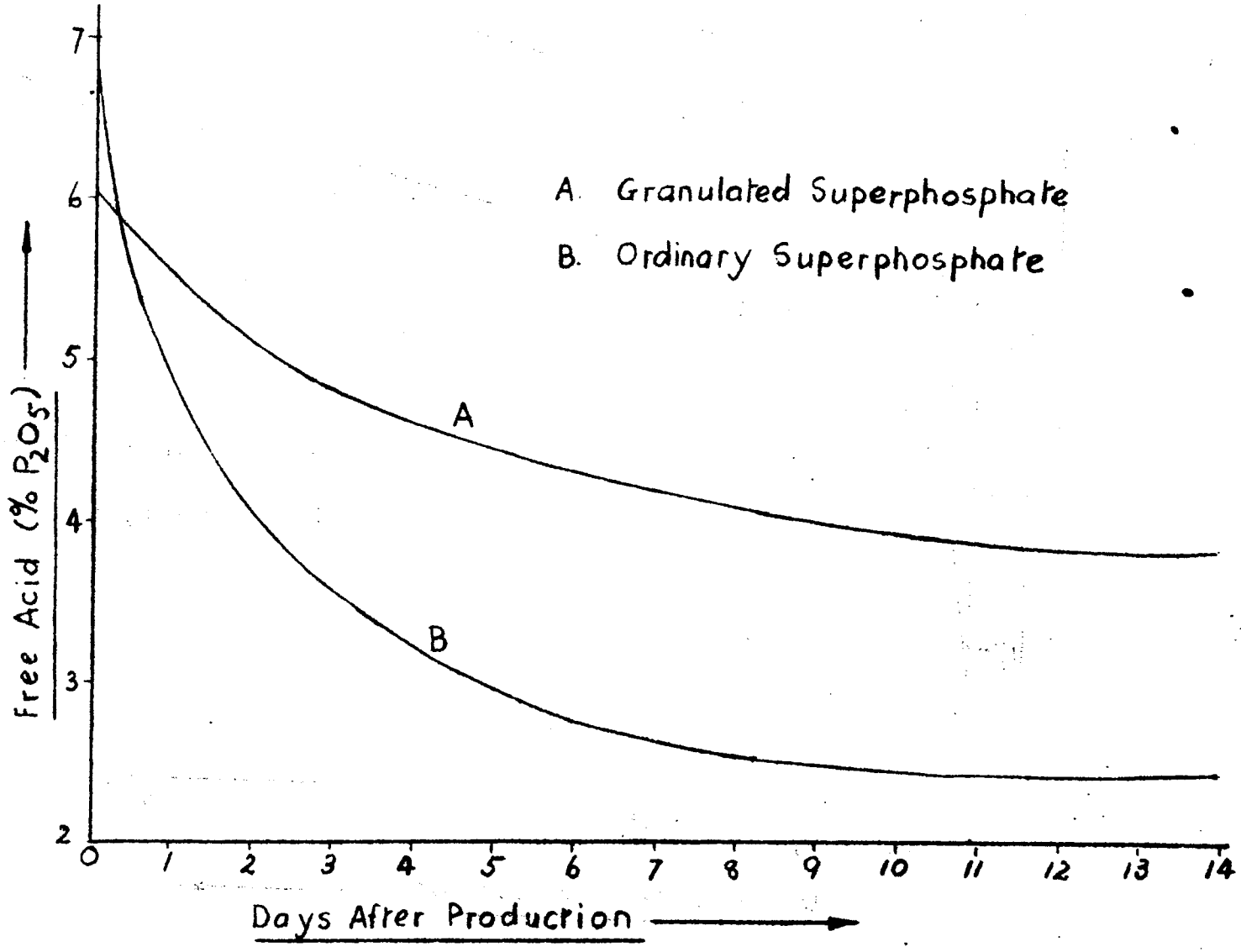


FIG II

CURING TIME CURVE - FREE ACID



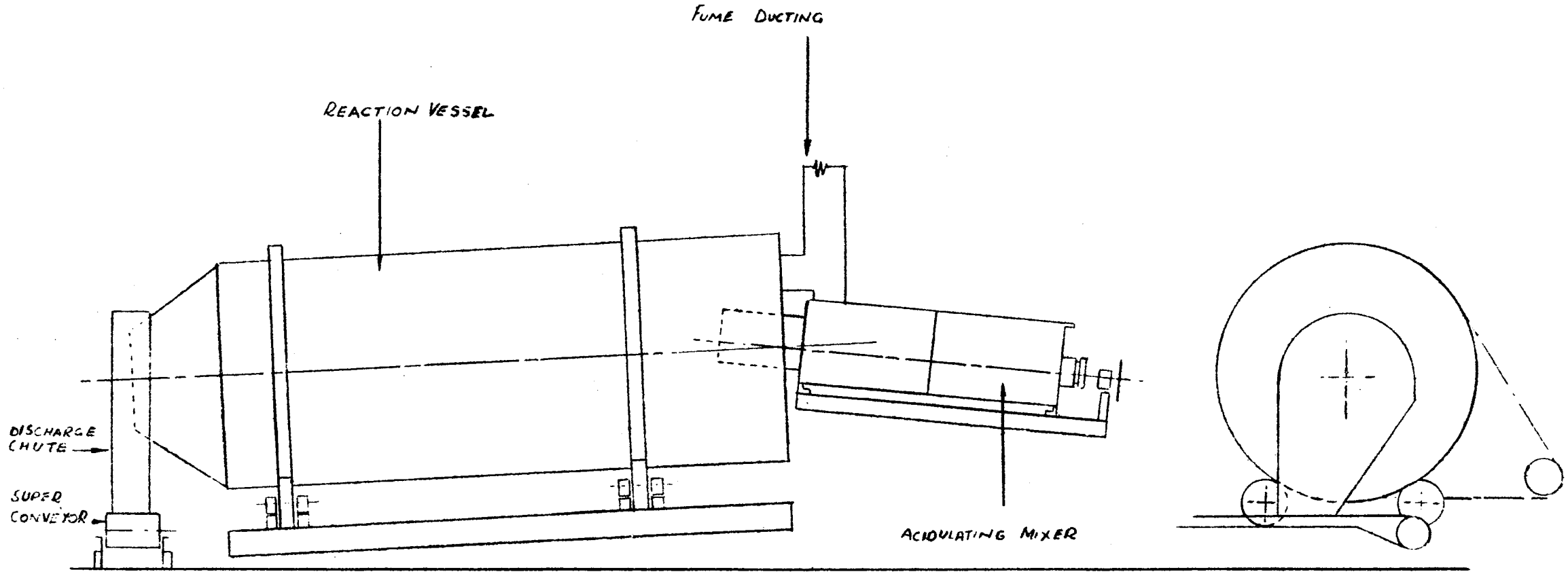


FIG III DIAGRAMMATIC ARRANGEMENT OF ROTARY DEN

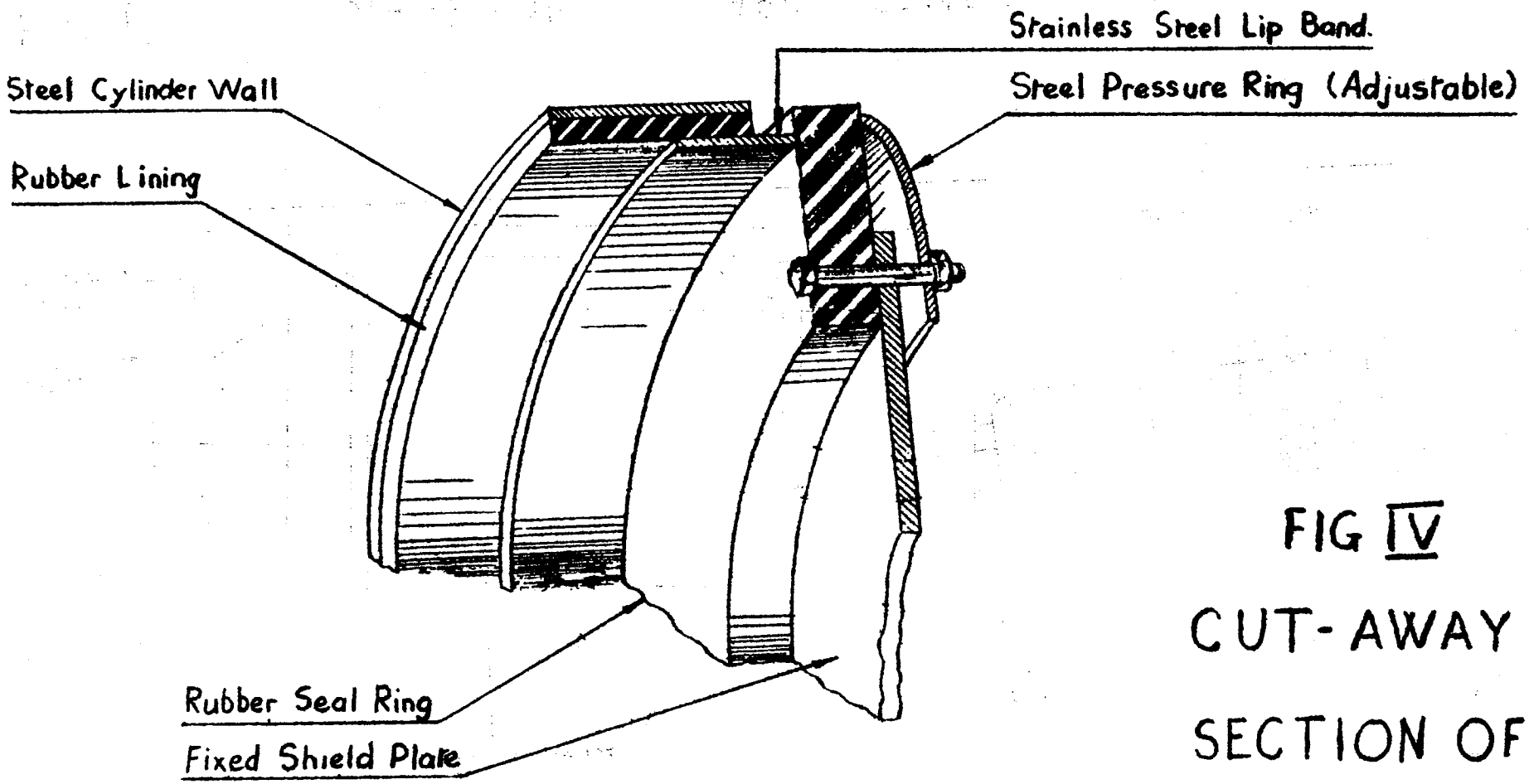


FIG IV

CUT-AWAY SECTION OF END-SEAL