THE EFFICIENT USE OF STEAM

WRITTEN FOR THE FUEL EFFICIENCY COMMITTEE
OF THE MINISTRY OF FUEL AND POWER

BY

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"In short, I expect almost totally
to prevent waste of steam"

JAMES WATT. Letter
to Dr. Lind, 1765

LONDON: HIS MAJESTY'S STATIONERY OFFICE

1947

Price £1 2*s*. 6*d*. net

438. STEAM ACCUMULATOR—RUTHS TYPE. The Ruths accumulator is shown in Fig. 253. It consists of a large steel cylindrical vessel nine-tenths filled with water. It is preferably arranged horizontally so as to give the largest possible surface of water for the liberation, as flash, of the stored steam.

One pipe A comes to the accumulator and steam either enters or leaves the accumulator through this one pipe. When the output of steam and the consumption of steam are equal there is of course no flow into or out of the accumulator. It would be silly to discharge and to charge the accumulator simultaneously ; so that one pipe is all that is necessary. The control of the accumulator is done by the two valves B and C whose action will be described later.

When steam is passed into the accumulator by the control valve B it must pass through the charging pipe D because the non-return valve E closes against it. The ingoing steam opens the charging non-return valve F and enters the charging manifold G to which are attached a number of nozzles well submerged in the water. The nozzles H, although projecting downwards, blow upwards inside the convection pipes K. Fig. 214b shows an enlarged section of a nozzle. The nozzles encourage rapid circulation, ensure quick mixing of the water in the accumulator and make certain that the steam will condense quickly and quietly without rattles and bangs.

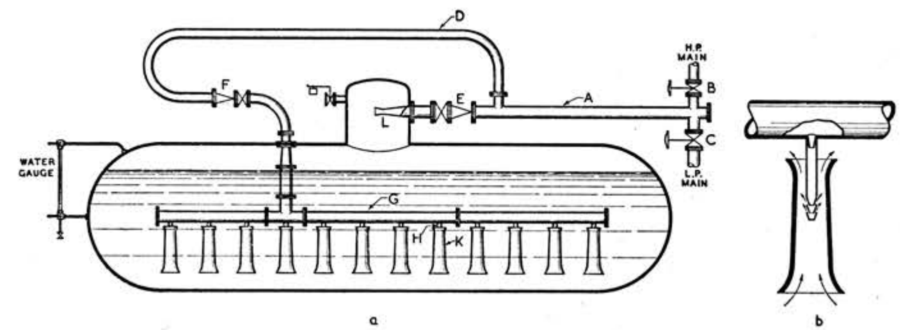

FIG. 253. RUTHS STEAM ACCUMULATOR

During charging the pressure rises in the accumulator, the water boiling point rises and so allows more steam to condense and more heat to be stored.

When the control valve C calls for a steam discharge from the accumulator the pressure in the pipe A falls below the pressure in the body of the vessel. Non-return valve F closes which prevents water being discharged, and non-return valve E opens and allows steam to escape. The lowered pressure in the accumulator causes the surplus heat in the water to be given up as flash. The nozzle L is a restriction on the flow of steam which prevents the steam discharging at a dangerously fast rate which might cause priming or carry-over. At ordinary discharge rates, the nozzle being of Venturi shape causes very little pressure drop. Any other form of restriction to the flow would cause a considerable irrecoverable pressure drop at all rates of flow.

439. STORAGE CAPACITY OF RUTHS ACCUMULATOR. The amount of steam that hot water can give up as flash has been discussed in Sections 44, 45 and 435. The water in an accumulator that is at work is always at the boiling temperature appropriate to the pressure in the vessel. This must be so, as were the water below boiling point the steam above it would condense until the vapour pressures had equalised ; were it hotter the surplus heat would cause a flash until the vapour pressures had similarly equalised.

The capacity of an accumulator for a given pressure drop is much greater at low pressures than at high pressures. A few examples will confirm this.

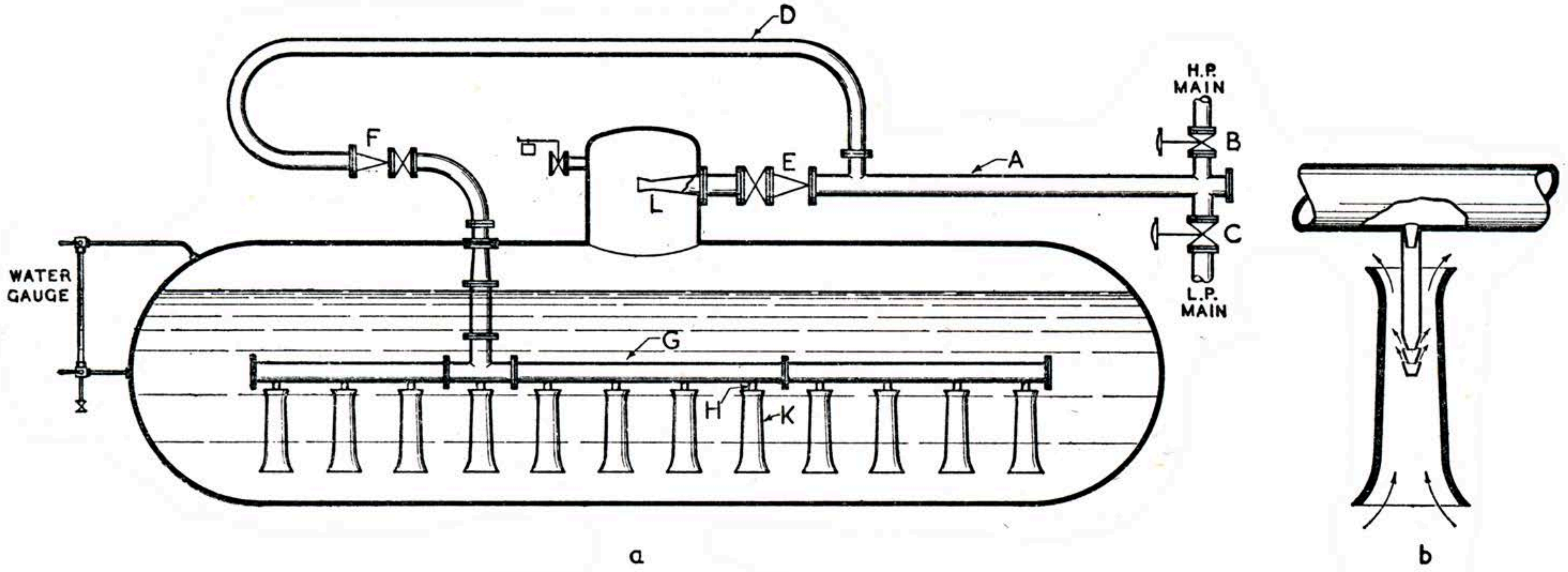

FIG. 253. RUTHS STEAM ACCUMULATOR

We will take a series of 20 psi pressure drops and work out the effects. Suppose we have a small accumulator containing 100,000 lb. of water. We can extract the following from the saturated steam table :—

Gauge Pressure	*Sensible Heat*	*Latent Heat*	*Total Heat*
0 psi	180·2	970·6	1150·8
20	227·5	940·1	1167·6
40	256·1	920·4	1176·5
60	277·1	905·3	1182·4
80	294·5	892·7	1187·2
100	309·0	881·6	1190·6

Let us see how much saturated steam at 20 psi.g. can be stored in 100,000 lb. of water at 212° F.

Let x = lb. of steam that can be stored

$$\text{Then } (100{,}000 \times 180{\cdot}2) + (x \times 1167{\cdot}6) = (100{,}000 + x)\, 227{\cdot}5$$

$$18{,}020{,}000 + 1167{\cdot}6x = 22{,}750{,}000 + 227{\cdot}5x$$

$$x = 5{,}031 \text{ lb. of steam stored.}$$

Let us now see how much steam will be given up when the accumulator is discharged from 20 psi.g. to 0 psi.g.

We have now $100{,}000 + 5031 = 105{,}031$ lb. of water at 20 psi.

When the pressure is reduced to 0 psi the surplus heat available for flash is $227{\cdot}5 - 180{\cdot}2 = 47{\cdot}3$ Btu/lb.

The total steam flashed will be $\dfrac{105{,}031 \times 47{\cdot}3}{970{\cdot}6} = 5{,}118$ lb. steam at 0 psi.

Working out the other pressure intervals and starting with 100,000 lb. in water at the lower pressure boiling point we get :—

Pressure Range	*lb. Steam Charged*	*lb. Steam Discharged*
0 to 20 psi.g.	5031	5118
20 to 40	3107	3137
40 to 60	2320	2335
60 to 80	1949	1959
80 to 100	1645	1651

It will be seen that we can take out rather more steam than we put in. This is because the total heat in saturated steam at one pressure is more than the total heat in the same weight of steam at a lower pressure (below 450 psi). Radiation loss from the accumulator, though very small—see Section 446—tends to cancel this because the heat loss results in condensation, and for practical purposes we can take output from an accumulator as being the same in weight as input subject to two considerations dealt with later.

Fig. 254 shows the storage capacity of 1 cu. ft. of water over various pressure drops at various pressures. Table IV in the Appendix shows the storage capacity in terms of per cent. of flash over a large range from 250 psi to 28 in. vacuum.

When using Fig. 254 care must be taken to use the correct water density, if the figures are to be converted back to lb. water instead of cu. ft.

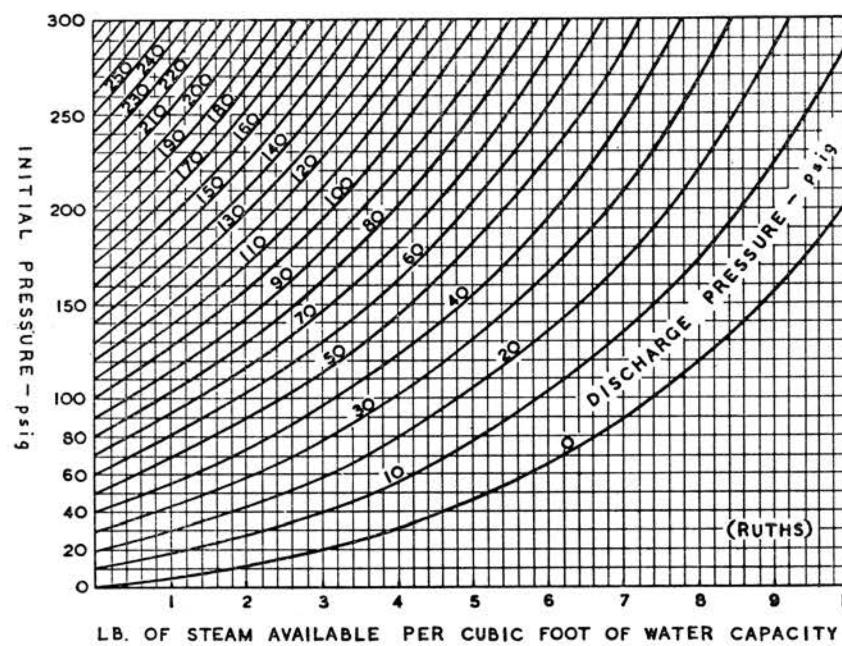

FIG. 254. STEAM STORAGE CAPACITY OF WATER

For example, flash from 80 psi.g. to 20 psi.g. gives from Fig. 254, 4·0 lb. flash steam per cu. ft. of water.

The volume of water at 80 psi.g. is found in the Steam Table to be ·0177 cu. ft./lb. Therefore the weight of water in 1 cu. ft. is $\dfrac{1}{\cdot 0177} = 56{\cdot}5$ lb.

Table IV says that over a pressure drop from 80 psi.g. to 20 psi.g. the flash will be 7·13 per cent. Now 7·13 per cent. of 56·5 lb. is 4·03 lb., so that when correctly used Fig. 254 and Table IV agree.

Had the water density at 20 psi been taken the water weight in 1 cu. ft. would have been $\dfrac{1}{\cdot 0171} = 58{\cdot}5$ lb. On this weight a 4 lb. flash only represents 6·84 per cent.

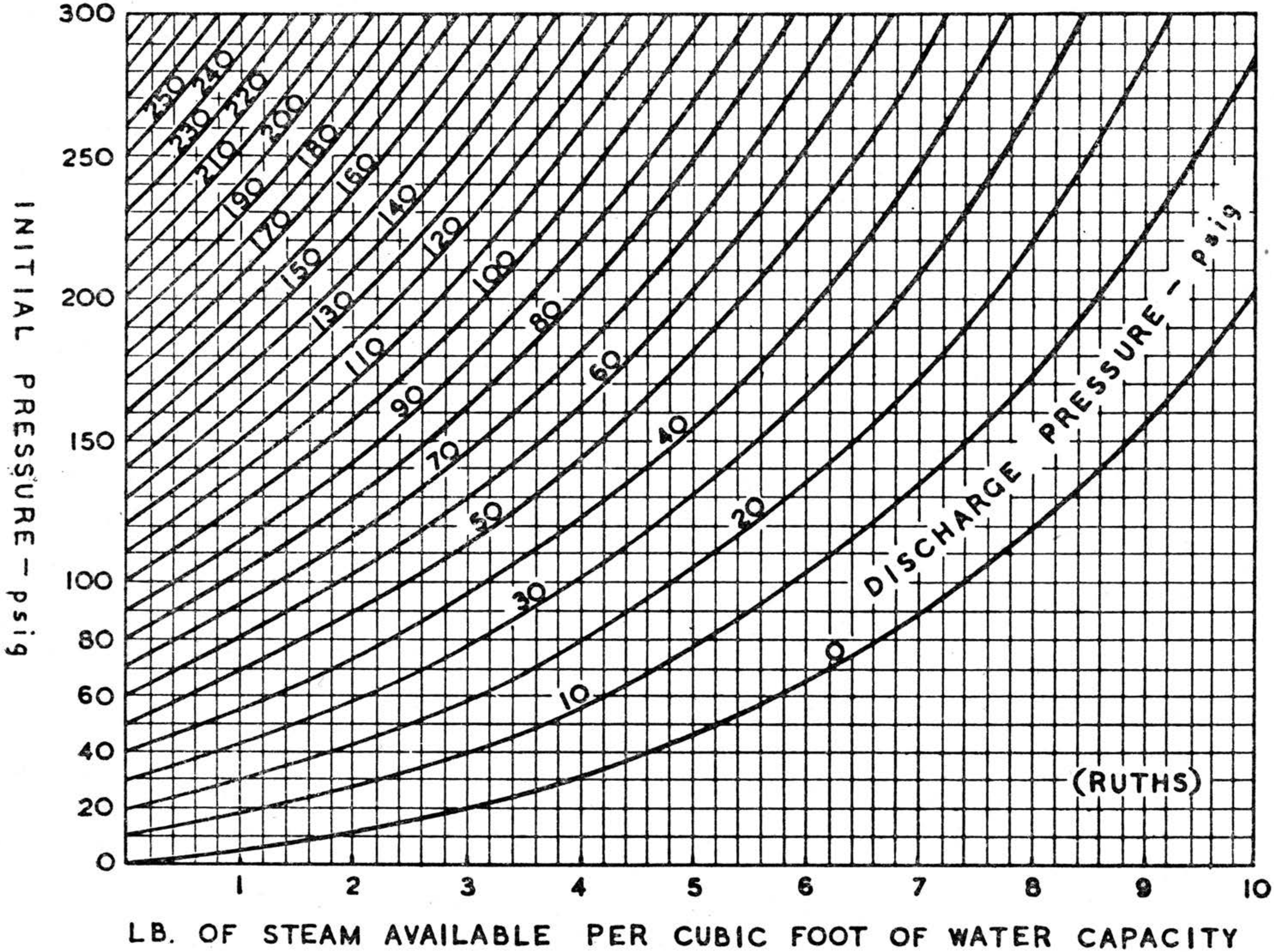

FIG. 254. STEAM STORAGE CAPACITY OF WATER