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# THE ENGINEERING SIDE OF FIRE-FIGHTING

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## 1. Introduction

"Man's destruction was first threatened by the Deluge and ever since it has been threatened by Fire."

The destructiveness of fire has never been disputed. The awe and fear aroused by it have often been taken as expressions of the majesty and power of deities, fierce and unmerciful.

Even to-day, when Man can pride himself on all-conquering progress in harnessing the forces of Nature, fire still reigns with undisputed sway as the greatest destructive agent in the world, against whose stronghold comparatively little headway appears to have been made.

The losses caused by fire in lives and money are colossal and increase year by year.

In olden days, one of the preventive measures adopted against fire was legislation which required all fires to be covered at the ringing of a bell at 7 or 8 P.M. This was the origin of the "*Curfew.*"

In London, prior to 1830, there were no organised bodies for fire-fighting. From 1832 to 1867, London was served by several fire brigades financed and run by various Fire Insurance Companies, separately and conjointly, from time to time.

In 1867, the Metropolitan Fire Brigade became the sole authority in London for the protection of life and property against the risks of fire.

In the Province of the Punjab, until very recently, except in the case of one or two of the largest towns, no place possessed anything which could, by any stretch of the imagination, be considered as a fire brigade worthy of the name even at that period, when the standards of fire brigades and equipment were much lower than to-day.

The incidence of fire in this province as well as several other provinces in India used to be very low mainly due to the simple manners of living of the people who did not keep much inflammable material in the way of furniture, clothes, curtains, etc., in their houses. Due to the changed way of living, especially amongst the more monied classes, the quantity of inflammable material in houses has increased considerably in recent years and this has increased the fire risk and the number of actual fires.

In 1934, the Punjab Government took up seriously the question of organising fire brigades in the towns of the Punjab and the Superintending Engineer, Public Health Circle, Punjab, was asked to inspect the existing fire brigade arrangements and advise local bodies regarding the formation and organization of their fire brigades.

In this connection, the Government published a circular on "Establishment of Fire Brigades in Municipalities under the Punjab Municipal Act," giving details of organization, equipment and establishment of fire brigades considered suitable for local conditions.

The necessity of taking precautions against fire outbreaks is always with us, but the importance of these arrangements is immensely magnified when war risks have to be taken into account as well because war introduces new factors and calls for very special precautions which do not enter into the problem in peacetime.

These factors include the following:

(*i*) The risk of the outbreak of a considerable number of fires in an air attack, using incendiary bombs or high explosive bombs.

(*ii*) Numerous fire outbreaks occurring in the same and various localities simultaneously.

(*iii*) In the event of an air attack, the normal water supply may be interfered with.

## 2. Fire Extinguishing Materials and Appliances

There are numerous materials used for fire-extinguishing purposes but by far the most important is water, and this paper deals only with fire-fighting appliances and equipment using water.

The water supply arrangements of towns consist of the following:

(*a*) Sources, such as percolation wells, storage reservoirs, tube-wells, springs, rivers, nallahs, etc.

(*b*) The conveyance of water from the source to the service reservoir by gravity or pumping.

(*c*) The distribution of the water through pipelines in the streets. The service reservoirs are usually less than 100 ft. above the ground surface, in fact in this province in many towns the reservoirs are less than 50 ft. above the ground. The towns are mostly built on flat plains. The pressure in the distribution mains seldom exceeds 100 ft. head or say, 44 lbs. per sq.* inch while in the vast majority of places including all towns in the plains the distribution pressure is probably less than 40 to 50 ft. head of water.

*1 lb. per sq. inch=2·3 ft. head of water.

For effective fire-fighting purposes a water jet under a pressure of usually not less than 40 lbs. per sq. inch at the branch pipe is required to be directed on the fire. This pressure, even without allowing for friction losses through fire hose, is not obtainable direct from the mains in any town in the plains, and as such, water has to be forced on to the fire by means of special fire pumps.

The fire-fighting arrangements of a town or other inhabited area may be classified under the following heads :

(*i*) Water supply distribution system ;

(*ii*) Valves and hydrants fitted in the distribution system ;

(*iii*) Connections between hydrants and the fire engines ;

(*iv*) Fire engines and pumps ;

(*v*) Fire hoses for the conveyance of water under pressure from the pumps to the scene of the fire ;

(*vi*) Branch pipes and jets.

In addition, there must be suitable personnel for operating the fire-fighting appliances, in the form of firemen, mechanics and, last but not the least, the directing head who is usually called the Fire Brigade Superintendent or Fire Station Officer.

## 3. The Water Supply Distribution System

In towns provided with piped water supply, the main distribution pipelines consist mostly of cast-iron mains and, in a few isolated cases, of steel pipes. Water for fire-fighting purposes is obtained through fire hydrants fitted on the distribution system.

It is beyond the scope of this paper to go into the details of sizes and types of pipelines to be used and it will suffice to say that on account of the low discharge of small pipelines under normal conditions, it has been found by long experience that fire hydrants fitted on mains less than 3-inch i/d (or less than 4-inch i/d preferably) are not effective. To be effective, each fire hydrant should have a minimum discharge of not less than 125 gallons per minute, with 5-ft. terminal head at the hydrant. This requires normally a distribution pipeline of at least 4-inch i/d. In large towns even this minimum discharge is quite inadequate and fire hydrants discharging from 250 to 500 gallons per minute are necessary.

## 4. Valves and Hydrants Fitted in the Distribution System

### (A) Valves

A sluice valve or gate valve is a contrivance by which the flow of water through a pipe may be regulated by a movable appliance or gate which opens or closes the passage-way. Those most commonly used in connection with water supply mains are known as sluice valves which have various types of ends, *i.e.*, flanges, sockets, spigots or other joints to fit in the pipelines as shown in Figs. 1 and 2.

These valves are operated by sluice-valve keys and usually open when the key is turned clock-wise (viewed from above).

A sluice valve should be fitted at each branch and in the mains at suitable intervals depending on local conditions.

Valves of the "Peat Valve" or "Globe" pattern in which the water has to travel through two right angles should not be used in connection with water supply distribution or fire-fighting appliances as they cause serious interference with the flow even when fully open.

## (B) Hydrants

### (*a*) *Introduction and History*

The development of the fire hydrant is rather interesting. In earlier days when wooden water supply pipes were used, in order to take off a supply of water for fire extinction purposes, a pit was dug to expose the pipe. A hole was then cut in the pipe, which was subsequently plugged by a wooden stopper or patch.

About the year 1800, improvements in the manufacture of cast-iron and consequent cheapening of its cost, were followed by the extension of the use of that metal in the manufacture of water mains, thus allowing for higher working pressures in the pipes. This brought into use the fire plug.

In early systems, right-angled, vertical branches were fixed in the pipe at irregular distances in the streets. These branches were closed by wooden tapered plugs driven in tight. Fig. 6 shows a water main, branch and plug in position, in addition to a cast-iron conical shield (to prevent the soil under the pavement from getting washed away). To obtain water, the turncock first cleared out the rubbish or packing in the hole; then, by tapping the upper end of the wooden plug, he loosened the same sufficiently to allow the water pressure to force the plug out (see Fig. 7). At points where the pressure was less, the wooden plug had to be drawn out by a spike. After ejecting the plug, a stand pipe as shown in Fig. 8 was fixed and joined to the hose.

In some cases, the plugs used to be ejected with such force that the job of fitting the stand-pipe was a work of great difficulty. The use of fire-plugs was wasteful both of water and pressure, besides which there was considerable risk of contamination of the water supply.

The next stage in the development consisted in the provision of "Ball Hydrants." These were usually fitted on flanged, vertical branches in the distribution system. The ball hydrant consists of two parts—the lower, bolted on to the branch on the distribution system and the upper to fit the stand pipe (see Fig. 9). This upper casting also acts as a seat for a ball, either of wood covered with *gutta-percha* or of vulcanite. The pressure in the pipe forces the ball up and on to the seat on the underside of the casting and keeps the hydrant outlet watertight.

To obtain water, a stand pipe, as shown in Fig. 10, is fixed on the hydrant and, by means of a screwed spindle through the standpipe, the ball is depressed off its seat and water passes into the standpipe.

This type of hydrant has the great advantage that it also acts as an air valve, but its use has been condemned because of the fact that it induces risk of contamination of the water, especially with intermittent water supplies, when the ball would automatically fall away from its seat—also there is great obstruction to flow due to the reduction of outlet area by the ball.

(*b*) *Types of Hydrants commonly used at Present*

An enormous number of different patterns of hydrants are manufactured. Some of these are shown in Figs. 11 to 20. Each manufacturer claims particular points of excellence. Cast-iron hydrants, suitable for distribution systems, most commonly used nowadays, are of two types, *viz.*, the screwdown ground hydrant (Figs. 11 to 15) and the sluice valve hydrants (Figs. 16 to 20). Both are generally fitted on flanged tees, the former on a tee fixed vertically, and in the case of the latter, the sluice valve is bolted on to a tee fixed horizontally and a 90-degree duck-foot bend with hydrant outlet is bolted to the sluice valve. Occasionally, a socketted sluice-valve is used in which case the tendency of the bend to work out by pressure must be counteracted by a concrete block on the other side of the bend. Sluice-valve hydrants are used mostly on large-size mains where very considerable quantities of water are available.

(*c*) *Outlets of Hydrants*

There are four types of hydrant outlets:

(*i*) The bayonet-joint outlet with lugs or hooks (Fig. 21), This type is used in a great number of government institutions at Lahore, Wherever these hydrants are to be provided it should always be seen that the distance between lugs or hooks is the same in order that standardized standpipes can be used with them;

(*ii*) The special bayonet-joint outlet, without lugs or hooks (Fig. 22). This type of outlet is not used in the Punjab. If and when required to be installed, the size of the outlet, its exact detailed design and make with makers' reference number should always be specified;

(*iii*) The "Morris" pattern instantaneous outlet (Figs. 23 and 24). This type is not used generally in the Punjab. If desired to be used, the male outlet is better because it is easier to connect up to the stand pipe when fixed in a pit or chamber in the ground ; and

(*iv*) The screwed male outlet (Fig. 25). In this case usually a loose cap fixed on a chain is fitted over the screwed outlet to protect the threads.

There are several descriptions of threads used such as :

(*i*) London Fire Brigade, V-thread (Fig. 26) ;

(*ii*) London Fire Brigade, Round-thread (Fig. 27) ; and

(*iii*) British Standard V-or Round-thread.

At Lahore, Amritsar, Sialkot and Rawalpindi, hydrants with $2\frac{1}{2}$-inch i/d male screwed outlets, with London Fire Brigade V-thread, are in use.

This type of outlet is most commonly used in the Punjab and is strongly recommended by the author, because it enables a watertight joint to be made which is important when a fire pump is coupled direct to the hydrant through a stand pipe—also the threads are easily cut locally.

(*d*) *Sizes and Spacings of Hydrants*

For average discharges, screw-down or sluice-valve fire hydrants with $2\frac{1}{2}$-inch i/d outlets, are most commonly used. For larger discharges, sluice-valve fire hydrants with outlets up to 4-inch i/d (and sometimes even bigger) are used.

Fire hydrants should not be spaced further apart than the distances given below :

| | |
|---|---|
| (*i*) In congested areas or places where important buildings or factories are sited and conflagration risk is high .. | 300 to 400 feet, in addition to clustering at all important crossings. |
| (*ii*) In ordinary built-up areas, with average fire risk .. | 500 to 600 feet. |
| (*iii*) In outlying areas, with low fire risks .. | 700 to 800 feet. |
| (*iv*) In no case more than .. | 1,000 feet. |

In important streets, where more than one main passes or crosses, an adequate number of hydrants should be provided on the larger mains and should be clustered at crossings.

(*e*) *General*

Hydrants must be constructed sufficiently strong to withstand very rough usage; they should be free in working, easy to repair and, above all, must have a clear and streamlined waterway, with the least practicable obstruction to flow.

(C) Indicator Plates

Indicator plates of porcelain enamel or cast-iron as per Figs. 28 to 31 should be fixed to buildings or walls at convenient places adjacent to all hydrants and sluice-valves, showing the distance from the plate to the valve or hydrant and the size of the main on which it is fitted, to demarcate their exact position and size of main on which fitted. Where walls are not available, these plates can be fixed on posts.

## 5. Connection between the Hydrants and the Fire Engines

(A) Stand Pipes

Stand pipes are used to receive water from the ground hydrants and make it available for use above ground in canvas dams (Fig. 32) or to be connected direct with the suction pipes of the fire pumps.

The stand pipes are usually made of a strong, seamless copper tube, the bottom end being of gunmetal, suitably designed to fit the particular type of hydrant it is proposed to be used with. The upper end is also made of gunmetal to fit the couplings used on the suction pipe of the fire engine and sometimes has swivel arrangements to turn the upper end in any required direction.

These stand pipes are fairly expensive but cheaper models can be made by using galvanised iron pipes and bends for the body, in place of seamless copper tube.

There are various types of stand pipe inlets and outlets as given below:

(*i*) *Inlets:*

- (*a*) Screwed, Male Bayonet joint (Figs. 33 and 37);
- (*b*) London Fire Brigade, Female, V-threaded (Fig. 34);
- (*c*) London Fire Brigade, Female, Round-threaded;
- (*d*) Morris Pattern, Female, Instantaneous (Fig. 35); and
- (*e*) Morris Pattern, Male, Instantaneous (Fig. 36).

(*ii*) *Outlets:*

- (*a*) London Fire Brigade, Male, V-threaded (Fig. 37);
- (*b*) London Fire Brigade, Male, Round-threaded; and
- (*c*) Morris pattern, Female, Instantaneous (Figs. 33, 34, 35 and 36).

Stand pipes with London Fire Brigade, V-threaded, Female Inlet, and V-threaded Male Outlet are recommended in cases where the stand pipes are to be connected directly with the suction pipes of the fire engines, as this arrangement gives fairly airtight connections.

Some engineers prefer London V-threaded Female Inlet and Morris Pattern Instantaneous Female Outlet. This also makes a fairly good connection but in the author's opinion the connection may not be airtight.

The following points should be observed in the design and construction of stand pipes and other fire fittings :

(*i*) Absence of steps, cavities or roughness of any kind in the interior ;

(*ii*) Clean external design, devoid of unnecessary excrescences ;

(*iii*) Lightness ;

(*iv*) Balance ;

(*v*) Alloys like gunmetal or phosphor bronze should be used wherever practicable, instead of brass, which may be weak and variable in quality ;

(*vi*) Use solid drawn and not brazed tubing, wherever possible ; and

(*vii*) All joints to be brazed and pinned.

(B) Connection between Stand Pipe (or Canvas Dam) and Fire Engine or Pump

This consists of internally reinforced Rubber Suction Hose varying from 2-inch i/d to 6-inch i/d according to the capacity of the pumps, with suitable couplings to fit the stand pipe outlet on one end and the engine suction connection on the other.

The couplings usually used are either London V or Round-threaded or Morris Pattern Instantaneous, both of which are suitable, but the author prefers the Threaded couplings for reasons already given.

It should be borne prominently in mind that couplings of all fire engines in one town should be interchangeable so far as practicable and suitable adaptors (Fig. 38) should be kept to fit the engines of near-by towns.

Couplings are either joined to suction pipes by clamps or wired on. Suction hose generally is not required for high internal pressures but has to be strong and reinforced to withstand against collapse or distortion due to external atmospheric pressure when under a vacuum. It usually consists of canvas-lined rubber and insertion, internally reinforced with spiral steel wire reinforcement embedded in the material.

## 6. Fire Engines and Pumps

(A) Introduction

A fire engine consists of a pump in which the water is subjected to pressure sufficient to raise it to the required height to produce, a jet. The modern pump draws water through an internally reinforced flexible suction pipe which is placed in a portable cistern or tank kept supplied with water or in a river, canal or pond or other source of water supply. In towns equipped with pressure water supply distribution, the suction pipe can be connected to one or more street hydrants, the engine thus being used to increase the pressure already existing in the distribution main.

For many years the manual fire engine was the only type evolved; then followed the steam fire engine which came into prominence during the later half of the nineteenth century. The average output of the horse-drawn steam fire engine was about 300 gallons per minute. These steam fire engines are not generally used now due to their being cumbersome and the time taken to raise steam.

### (B) Modern Fire Pumps

Modern fire pumps are driven by internal combustion engines run mostly on petrol as fuel.

Some of these pumps are fitted on a motor chassis and are driven by a motor engine through suitable gearing while others, though fitted on the motor chassis, are driven by their own independent internal combustion engine.

It is sometimes difficult to take such engines over soft ground or through narrow streets or places where a motor vehicle cannot easily pass. This has led to the development of fire pumps with engines fitted on small trailers which can be hitched to the back of a car or other vehicle. In narrow thoroughfares, where the towing vehicle cannot go, the trailer is drawn to the scene of the fire by manual labour.

In almost every case, the motive power used with these pumps, consists of an internal combustion engine (very often, car or motor lorry engines of popular makes such as "Dennis," "Austin," "Standard", "Ford", "Leyland", "Morris," etc.) connected by flexible coupling with the pump.

There are three types of fire pumps commonly used:

(*i*) Reciprocating;
(*ii*) Rotary; and
(*iii*) Centrifugal or Turbine.

### (C) Reciprocating Pumps

Reciprocating fire pumps should not have less than three cylinders. The Merryweather "Hatfield" is one of the best known reciprocating fire pumps designed for use in connection with petrol engines. It is compact, having three separate pumps each complete with plungers, valves, etc., drawing from a common suction chamber and delivering into a common delivery (see Figs. 39, 40 and 41). It will be seen that each pump occupies one-sixth of the hexagon and is worked from a single crank.

Reciprocating pumps are direct in action. When kept in good order, the slip through their pistons and valves is very little and therefore, the discharge depends on the area of cylinder, length and number of strokes per minute. When the piston is drawn out, the space in the barrel must contain either water or air; thus, if the suction is tight, the pump will exhaust air and by tending to produce a vacuum, cause the water to rise and enter the pump. With a pump with valves, etc., in good order, a vacuum of almost 24* inches of mercury or 27 feet of water should readily be obtained.

(D) Rotary Pumps

Rotary pumps are used in relatively few cases in America and Europe. They consist of a pair of interlocked vanes or rotors running inside a casing (see Fig. 42).

As the vanes revolve, water is pushed up, causing suction in the suction chamber.

A certain percentage of water carried by vanes slips back to the suction side which is unavoidable. This slip tends to increase with the wearing of the vanes and sometimes may amount to a very considerable proportion of water pumped.

The number of vanes varies but seven is the most common. In the case of rotary pumps dealing with dirty and gritty water, the wear in the vanes may be considerable and the losses in slip and friction are liable to be heavy. For these reasons, the demand for this type of fire pump is not considerable.

(E) Centrifugal or Turbine Pumps

The centrifugal pump is simple in the extreme and it has neither plungers nor pistons. The essential parts consist of the casing, usually of cast-iron, rotors or impellers, either of cast-iron or bronze, with six to twelve curved vanes depending upon the design of the maker. Water entering at the centre or eye of the impeller is flung outwards by the centrifugal force set up by the rotation of the impeller, causing pressure at the vane tips and vacuum at the centre.

Turbine pumps are of the centrifugal type, the difference being that the turbine pump has guide vanes while the centrifugal pump has not. Figs. 43 and 44 show the essential difference between the common centrifugal pump and a turbine pump. It should be noted that turbine pumps wear comparatively rapidly if used for pumping gritty water. The quantity of water delivered by a centrifugal or turbine pump varies approximately as the speed and the pressure varies as the square of the speed, consequently the horse power absorbed varies roughly as the third power of the speed. To avoid excessively high speed and extra-large size of impellers, when higher

*1 inch of Mercury = 1.132 ft. head of water.

pumping pressures are required, a number of impellers are arranged in series, forming a multistage centrifugal or turbine pump.

Where the head is such that a large number of stages is to be used, a turbine pump should be used in preference to a centrifugal.

In case of fire engines of the smaller sizes, normally single-stage or double-stage pumps are used but sometimes three or four-stage pumps may be required.

In Appendix III annexed, the characteristic curves of some of the popular types of trailer fire engines fitted with centrifugal or turbine pumps in use with the Punjab A. R. P. services, are given.

The efficiency of centrifugal or turbine fire pumps usually varies from 50 to 70 per cent. or more depending on working conditions.

Centrifugal or turbine pumps when required to draw water from a level below that of the pump, which must not exceed about twenty feet, have to be provided with air exhausters to exhaust air from the suction pipes or the suctions must be provided with foot valve and suitable priming arrangement. In the case of fire pumps, as time is an important factor, efficient exhausters should always be fitted in order that the suctions shall be charged rapidly.

Whenever pumps are run, whether for testing or other purpose, they should be charged with water to prevent damage occurring due to overheating of glands, etc.

(F) General

The following table gives particulars of the maximum theoretical suction lift of pumps at various altitudes above sea level at standard barometric pressure based on 14.7 lbs. per sq. inch at sea level:

| Altitude | Barometric pressure in lbs. per sq. inch | Equivalent head of water in feet (theoretical suction lift) | Maximum practical suction lift of pumps in feet assuming no friction losses |
|---|---|---|---|
| Sea level .. | 14·7 | 33·93 | 25 |
| ¼ mile or 1,320 ft. above sea level | 14·02 | 33·38 | 23 |
| ½ mile or 2,640 ft. above sea level | 13·33 | 30·79 | 22 |
| ¾ mile or 3,960 ft. above sea level | 12·66 | 29·24 | 21 |
| 1 mile or 5,280 ft. above sea level | 12·02 | 27·76 | 20 |
| 1¼ mile or 6,600 ft. above sea level | 11·42 | 26·38 | 19 |
| 1½ miles or 7,920 ft. above sea level | 10·88 | 25·13 | 18 |
| 2 miles or 10,560 ft. above sea level | 9·88 | 22·82 | 16 |

It will be seen that at Lahore 700 ft. above sea level the theoretical lift is about 33 ft. while at Simla about 7,000 ft. above sea level it is only 26 feet. The maximum practical suction lift obtained even with well-made ram or plunger pumps is usually not more than 70 per cent. of the theoretical lift and is given in the last column of the Table. Thus it will be seen that whereas at sea level a maximum lift of about 25 ft. may be obtained under favourable conditions, at Simla only about 18 feet should be expected.

Almost all types of pumps, however, work at their best at sea level when the suction lift is less than 17 ft.

At places with spring level deeper than 16 to 18 feet below ground level, auxiliary pumping plants which should be placed preferably within 3 to 8 ft. of spring level must be lowered into the well and fixed on a platform which may be slung into the well or suspended from the surface.

In such cases, a suitable arrangement to discharge exhaust gases clear of the well should be made.

In cases of fires a long distance away from the source of water, several fire pumps or auxiliary pumps may have to be fitted in series or relays to boost the supply to the scene of the fire.

When using water which carries floating materials, detritus, etc, a basket strainer as well as a copper strainer should be fitted at the end of the suction (See Figs. 45 and 46).

### 7. Fire Hoses for Conveyance of the Water under Pressure from the Pump to Scenes of Fires.

Early fire engines consisted of a pump with its lower part fixed inside a tank fed by water. The pump, when worked, forced water on to the fire through a short-delivery stand pipe with the outlet end tapered to produce a jet.

To use such engines to the best advantage, the pump had to be placed as near to the scene of fire as possible. This restricted its effective range.

#### (A) Leather Fire Hoses

About the year 1672, a Dutchman hit upon the idea of making a leather hose or pipe made of strips of leather sewn together, and inserting it between the pump and the nozzle.

In 1808, sewn pipes started giving way to rivetted pipes but these used to leak badly.

About 1819, methods of manufacture of copper rivetted leather pipes were considerably improved and watertight pipes were produced (see Fig. 47).

Leather hose pipes are strong, they offer good resistance to internal pressure and, if well looked after, will last for many years. They, however, possess the great disadvantage of being bulky, heavy, comparatively inflexible, difficult to handle and they offer greater resistance to flow than canvas hoses.

(B) Woven Fire Hoses

Till about 1874, when the manufacture of flaxen hose was introduced, leather hoses were most commonly used.

At first flax hose was entirely woven by hand but, during more recent years, weaving processes have been so improved that machine-made hose can now be obtained which is almost equal in quality to handwoven hose.

Hose can be made watertight by good, close weaving but this increases its rigidity, which is objectionable. When a hose is first used, it leaks or sweats, but, in due course, the water causes the fabric to expand and reduces the sweating. This swelling is partly permanent, hence a good, well made hose, which has been used several times, will be nearly watertight.

Materials which swell in the manner described above and commonly used for manufacture of hoses are hemp, cotton, jute and flax. Hemp fibre is strong but brittle and lacks elasticity and it is only employed in hoses of inferior quality not used for pressure.

Cotton stretches very much under pressure and, as such, is of no use in unlined fire hoses.

Jute fibre is very coarse and weak and unsuitable for high-pressure fire hoses.

Flax is the best fibre for manufacture of fire hoses. It is strong to withstand the pressure, wears well, is soft and pliable and expands when wet.

The strength and thickness of woven hose depends on the material used in weaving.

The requirements with which fire hose must comply are asfollows :

(*i*) Sufficient strength to withstand safely the greatest pressure the hose is likely to be subjected to even after many years of use :

(*ii*) Resistance to leakage at all times to reduce loss of pressure and unnecessary damage by water to a minimum ;

(*iii*) It should be sufficiently flexible and light and afford a low frictional resistance to flow of water.

(C) Rubber-lined Fire Hoses

To reduce the loss of water and pressure in the hose through leakage and sweating, rubber-lined fire hoses are commonly used in some countries. This type of hose offers less resistance to the flow than unlined fire hose such as flax (see Figs. 48 and 49). Rubber-lined fire hose should only be supplied to those fire brigades which can look after the hose scrupulously.

Moreover, the life of the hose is that of the rubber-lining which, more particularly in hot countries, is especially liable to deterioration.

(D) Sizes and Capacities of Hoses

Fire hoses most generally used are of $2\frac{1}{2}$-in., $2\frac{3}{4}$-in. and 3-in. i/d, those most commonly used being $2\frac{1}{2}$ in. i/d and $2\frac{3}{4}$-in. i/d, but of recent years a strong tendency to use larger diameter hose, usually $3\frac{1}{2}$-in. i/d, has been noted especially in connection with large Fire Brigades.

The types of couplings for joining the hoses together generally in use are :

(*i*) The London Fire Brigade screwed couplings with round or V-thread (Figs. 50 and 51) ; or

(*ii*) An Instantaneous Coupling such as the "Morris" Pattern.

The latter is the one which has been recommended for universal use in the Punjab and it is depicted in Fig. 52.

The grooved tail pieces of the couplings are joined with the hoses by wire as shown in Fig. 53 or by collar or ferrule as in Fig. 54.

Fire hose is usually laid out for use at fires so that the female coupling is leading.

The average loss of pressure due to friction in lined and unlined fire hoses is given in Appendix II annexed. A few approximate figures are tabulated below. The actual friction varies with various makes of hoses and their materials and, in the case of rubber-lined hoses, with the type of rubber lining and its manufacture.

TABLE

Loss of head in lbs. per sq. inch through 100 linear feet of various types of hoses

| *Discharge in gallons per minute* .. | *50* | *100* | *150* | *200* | *250* | *300* |
|---|---|---|---|---|---|---|
| $2\frac{1}{2}$-in. i/d Canvas Flax Hose .. | 2.1 | 8.3 | 19 | 33 | 52 | 75 |
| $2\frac{3}{4}$-in. i/d Canvas Flax Hose .. | 1.3 | 5.1 | 12 | 20 | 32 | 47 |
| $2\frac{1}{2}$-in. i/d Rough Rubber-lined Hose .. | 1.4 | 5.5 | 13 | 22 | 35 | 50 |
| $2\frac{3}{4}$-in. i/d Rough Rubber-lined Hose .. | 0.9 | 3.4 | 7.8 | 14 | 22 | 31 |
| $2\frac{1}{2}$-in. i/d Smooth Rubber-lined .. | 1.0 | 4.1 | 9.3 | 17 | 26 | 37 |
| $2\frac{3}{4}$-in. i/d Smooth Rubber-lined .. | 0.6 | 2.5 | 5.8 | 10 | 16 | 23 |

The loss of head due to friction in the same size, type and length of hose is roughly proportionate to the square of the velocity of flow, hence four times the pressure will be needed for pumping twice the quantity of the water through fire hose of the same length and description.

The loss of head due to friction through fire hose of the same length and description but of different internal diameter is directly proportional to the fifth power of the internal diameter. Thus the power required to pump the same quantity of water through $2\frac{3}{4}$-in. i/d hose will be only .62 of the power required to pump it through $2\frac{1}{2}$-in. i/d hose.

In cases where a volume of water in excess of the quantity which can, with comparatively little loss of head, be passed through a single line of hose, is required at a fire, then a number of fire hoses have to be laid in parallel.

The effect of pumping through single and double lines of $2\frac{1}{2}$-in. and $2\frac{3}{4}$-in. i/d flaxen canvas hose, 300 ft. long, is shown below. The quantity pumped is assumed at 300 gallons per minute :

*Case I—Single line of $2\frac{1}{2}$-in. i/d Canvas Flaxen Hose*


Total loss of head = 75 lbs./□" + 75 lbs./□" + 75 lbs./□" = 225 lbs./□"

*Case II—Double Line of $2\frac{1}{2}$-in. i/d Canvas Flaxen Hose*


Total loss of head = 19 lbs./□" + 19 lbs./□" + 19 lbs./□" = 57 lbs./□"

*Class III—Single Line of $2\frac{3}{4}$-in. i/d Canvas Flaxen Hose*


Total loss of head = 47 lbs./□" + 47 lbs./□" + 47 lbs./□" = 141 lbs./□"

*Case IV—Double Line of $2\frac{3}{4}$-in. i/d Canvas Flaxen Hose*


Total loss of head = 12 lbs./□" + 12 lbs./□" + 12 lbs./□" = 36 lbs./□"

These diagrams illustrate the value of the use of parallel lines of hose and economy in loss of pressure by the use of hose of larger diameters.

The splitting-up of the lines of hoses is effected by means of dividing and collecting breechings as shown in Figs. 55 to 57.

This method can be used for joining up two, three, four or more lines of suction pipes also when required.

Hose ramps (Figs. 57 to 59) should be used to prevent damage by traffic when a hose is laid across a street.

Hose hooks or slings as shown in Figs. 60 to 63 are used for carrying hose above ladders, etc.

(E) Maintenance and Repairs of Hoses

Fire hoses (lined or unlined) should be thoroughly dried after use by laying out on the ground or on drying racks (see Fig. 64).

After thoroughly drying, the outside surface should be cleaned and the hose rolled, with the female coupling forming the core of the roll, and stored in a dry place.

Figs. 65 and 66 show simple machines for cleaning and rolling the hose.

There are various types of hose-repairing outfits on the market. Usually these work on the principle of vulcanising the rubber of a patch over the damaged portion, but there are also several rather novel methods in use.

One of these provides for putting a washered rivet through the leaky hole to stop the leak. This is useful in the field for temporary repairs.

Hose-clamps and binders as shown in Figs. 67 to 70 are useful for stopping a leak in the field.

## 8. Branch Pipes and Nozzles

Branch pipes are made of streamlined, burnished copper, tapered tube with gunmetal coupling at the base to suit the couplings used with the fire hose and a screwed gunmetal joint at the top to take the nozzle.

Nozzles consist of round and hexagonal gunmetal fittings, with recessed top, burnished inside and with the aperture usually made in accordance with the formula for streamlined jets.

Branch pipes with round and hexagonal nozzles are shown in Figs. 71 to 73 and nozzles in Figs. 74 and 75.

Particulars of the pressure of water required to produce jets of various sizes and effective lengths, through nozzles ranging from $\frac{1}{4}$-in. to $1\frac{3}{8}$-in. i/d are given in Appendix I annexed.

It will be observed that jets of small diameter discharge much smaller quantities of water as compared with larger jets, at the same pressure and at the same time, the effective height and horizontal length of the jet becomes greater as the diameter is increased.

Some fire engineers consider that for nozzles of $\frac{3}{4}$-in. i/d or over the maximum economical jet velocity is 120 ft. per sec., while 90 ft. per sec. produces a good fire stream and 60 ft. per sec. a weak fire stream. The pressures required for these velocities are 97, 54 and 24 lbs. per sq. inch respectively.

In the writer's opinion, the maximum pressure at nozzles should not exceed the following limits:

| *Bore of nozzle* | *Pressure* | *Theoretical jet velocity Ft./Sec.* |
|---|---|---|
| Up to $\frac{1}{4}$ in. .. .. | 70 lbs. | 102 |
| $\frac{1}{4}$ in. to $\frac{5}{8}''$ .. .. | 80 lbs. | 109 |
| $\frac{5}{8}$ in. to 1 in. .. .. | 90 lbs. | 116 |
| 1 in. to $1\frac{3}{8}$ in. .. | 100 lbs. | 122 |

The increased pressure above 100 lbs. per square inch does not result in anything like proportionately increased effective height of jet; and the increase of power to produce jets of greater heights than those caused by 100 lbs./sq. inch pressure is out of proportion to the results obtained.

On the other hand, for reasonably efficient fire-fighting purposes, water should be delivered at the nozzles at a pressure of not less than 40 to 50 lbs. per sq. inch.

An approximate formula for the discharge through nozzles in gallons per minute for 50 lbs./sq. inch pressure is $180d^2$ and for 100 lbs./sq. inch, $250d^2$. ($d$=diameter of nozzle in inches.)

The discharge of a nozzle is roughly proportionate to the square of its diameter, the pressure remaining the same.

It is quite useless to use large-size nozzles with fire pumps which cannot deliver the quantity of water passed through such large nozzles at suitable pressure.

The tables given in Appendix I should, therefore, be most carefully studied to avoid making ridiculous mistakes in the selection of sizes of nozzles to suit the fire pumps in use.

This is mentioned particularly as it is frequently lost sight of at the time of a fire.

*Special Patent Nozzles*

There are certain patent nozzles. The Standard "London" Nozzle (see Fig. 76) is provided with $\frac{3}{4}$-inch i/d jet and can produce the following :

(*a*) A solid $\frac{3}{4}$-inch jet ;
(*b*) A smoke-driving screen ;
(*c*) A solid jet and screen simultaneously ; and
(*d*) Shut off, either spray or jet.

In the "Pouderoux" Diffuser (see Fig. 77) in addition to throwing a straight jet, water can be whirled centrifugally under pressure and broken down to fine uniform vapour which can be safely directed on high tension cables.

The "Pouderoux" Diffuser is fitted on the branch pipe in place of a nozzle.

The "Nelson" Nozzle is somewhat similar to the London Nozzle when in action (see Fig. 78).

By the operation of a hand wheel, the following six different phases can be produced :

(1) A complete shut-off ;
(2) A first-aid jet ;
(3) A powerful solid jet ;
(4) A concentrated spray ;
(5) A wide-angle smoke-driving spray ; and
(6) A solid jet combined with any adjustment of spreader.

## 9. Special Equipment for Air Raid Precautions

(A) Introduction

It is opportune in view of the present war situation to give particulars in this paper of special equipment which has been found suitable in Great Britain for dealing with incendiary bombs and fires caused by them.

Typical incendiary bombs consist of thick-walled tubes of aluminium, elecktron or inflammable alloy of magnesium, aluminium and zinc, filled with an igniting compound, principally "thermite." These bombs weigh from 2 to 60 lbs. but the smaller type, weighing nearly $2\frac{1}{4}$ lbs. and known as the "kilo" bomb, is most generally used due to its lightness.

The "kilo" bomb consists of a 2-inch diameter circular cylinder, 10-inch long, with 5-inch long metal stabilizers or vanes forming its tail (see Fig. 79). No matter how many fire brigade units may be available in a town, the number of fires which are liable to be produced by even a few æroplanes dropping incendiary bombs are so great that the fire brigades would probably be unable to cope with even a fraction thereof; hence it is necessary that householders and other persons in charge of buildings and institutions as well as A. R. P. personnel shall be provided with small hand-operated appliances to deal with burning bombs and incipient fires.

It may be beyond the capacity of a house-holder to fight a large incendiary bomb for which the fire brigade should be called, but small incendiary bombs are comparatively easy to tackle and every householder should be trained to equip himself with the necessary appliances and know how to use them for rendering the bombs innocuous and dealing with incipient fires caused thereby.

### (B) Method of Air Attack

Aeroplanes, each carrying anything from a thousand to three thousand "kilo" bombs, when flying near a target, are able to discharge these small incendiary bombs in salvoes of twenty or more at a time, by which means a number of fires may be started simultaneously.

### (C) Action of the Incendiary Bomb

A "kilo" bomb dropped from a height of 5,000 ft. above the ground attains a velocity of 350 ft. per second near the ground. With the momentum thus gained, it can penetrate a roof of reinforced concrete 4-inch thick, or a steel plate $\frac{1}{4}$-inch thick, or a layer of bags closely packed with dry sand. When the bomb hits a hard surface, a needle is driven into a small percussion cap in the nose of the bomb which ignites the thermite. The thermite ignites to a white incandescent heat of about 2,500°C. temperature, emitting jets of flames and molten metal violently through the vent holes of the bomb all over the place, thus starting incipient fires.

In a minute or so, the metal casing gets well alight. This burns at a temperature of nearly 1,300°C. and gives off a dazzling light, while the molten burning metal therefrom can easily penetrate through an ordinary flat or corrugated iron sheet.

An incendiary bomb does not explode unless water is thrown on it. It is violent for the first minute or so until the "thermite" burns out but afterwards it burns more steadily.

### (D) Appliances required to Fight Incendiary Bombs

The following appliances are required to fight incendiary bombs or to prevent incipient fires therefrom so far as possible.

*(i) The Stirrup Pump*

This is a simple single-cylinder single acting brass-barreled plunger pump capable of pumping about $1\frac{3}{4}$ gallons of water per minute (see Fig. 80). It is fitted with a length of rubber insertion, delivery hose with an $\frac{1}{8}$-inch dia. plain nozzle at the end, which will give a jet of about 30 ft. in length and also a spray-making nozzle to give very fine atomised spreading spray (Fig. 81).

A dual-purpose nozzle to provide both a jet and an atomised spray by turning a lever and without actually taking off the nozzle has been designed in the Public Health Circle, Punjab, for use with stirrup pumps manufactured locally at Lahore, as shown in Fig. 83.

This pump, as approved by the Home Office in England, is provided with 30 ft. of delivery hose. This length is found necessary there to enable fires in the lofts of pent roofs to be tackled, but as such type of construction is not usually adopted in this part of the world, a length of ten to fifteen feet of delivery hose is considered sufficient here. However, in hill tracts, such as Simla, Kangra, Murree, etc., where pent roofs are used, stirrup pumps should be provided with 30 ft. length of hose.

*(ii) The "Redhill" Equipment*

A set of "Redhill" Equipment consists of a metal sand container to hold approximately 30 lbs. of sand, a scoop and a rake. The rake and scoop of the Standard Redhill Equipment approved by the Home Office in England [as shown in Figs. 84(*a*) and (*b*)] are provided with 1-inch dia. ashwood handles with bayonet joints so that both handles can be joined together to give extra length in case of necessity.

In the Punjab, suitable ashwood is not available at reasonable cost and light "female" bamboo handles, 7-ft. 6-in. long for the scoop and 5-feet long for the rake have been provided (as shown in Figs. 86 and 87).

*(iii) Dark Glasses*

A pair of cheap, dark-blue glasses with a metal frame should be worn to protect the eyes from the dazzling effects of light emitted by an incendiary bomb.

*(iv) Sacking*

Pieces of gunny or old sacking are required to be wetted and wrapped round the legs to protect the legs when working the appliances.

(*v*) *Kerosene oil tins or buckets* full of water with arrangements for replenishing these quickly should also be provided.

(E) Method of Fighting Incendiary Bombs

The igniting compound of an incendiary bomb, *i.e.*, thermite, contains its own stock of oxygen and cannot be extinguished by ordinary means. The thermite, however, burns out in a minute or so.

When a burning incendiary bomb is discovered, it should be remembered that the fires caused by the bomb are much more important than the bomb itself. These fires should, therefore, be brought under control or extinguished as quickly as possible, while the surroundings of the bomb, including all inflammable objects such as curtains, furniture, carpets, clothes, wooden articles, etc., within its radius of action should be kept wet by pumping a jet of water from the stirrup pump thereon. At the same time, great care must be taken not to direct the water jet on the bomb itself which, if brought in contact with water, is liable to explode, throwing pieces of burning and molten metal all round, each one of which may cause a fire.

After putting out incipient fires and wetting the area around the bomb, the bomb has to be dealt with.

As soon as the thermite of the bomb is burnt out, sand should be placed on the bomb by means of the long-handled scoop so as to cover it with about 2 inches of sand all round. This sand will cut off the supply of oxygen to the bomb and reduce its activity, making it almost innocuous. Then, with the help of the rake, the bomb, surrounded by sand, should be raked into the scoop, thrown into the sand container, covered with sand and removed to a safe place to burn out.

If an incendiary bomb drops in the open or other safe place where it cannot start a fire, it may be allowed to burn itself out. If, however, the rate of combustion of the bomb needs to be accelerated, the fine atomised spray from the special nozzle of the stirrup pump can be directed straight on the bomb. The decomposition of the atomised water will provide the extra supply of oxygen required to enable the bomb to burn up quickly.

## 10. Equipment and Personnel for Fire Brigade equipped with small or medium-size Trailer Fire Engines.

The equipment and personnel required for each trailer fire engine unit will vary considerably, depending on local conditions, but in order to give some indication as to the equipment and personnel likely to be needed with each trailer fire pump, the following particulars are given. These would constitute a fair provision to enable reasonable efficiency to be maintained, but in many cases additional personnel and also equipment, especially greater length of delivery hose, would be required.

(A) EQUIPMENT FOR A FIRE BRIGADE UNIT PROVIDED WITH A SINGLE SMALL OR MEDIUM SIZE TRAILER FIRE PUMP.

| *Description of item of equipment* | *For places with piped water supply* | *For places without piped water supply* | *Remarks* |
|---|---|---|---|
| Armoured suction hose with couplings .. | 30 ft. | 50 ft. | |
| Hydrant cover keys .. | 2 Nos. | .. | |
| Hydrant keys .. | 2 Nos. | .. | |
| Stand pipes .. | 2 Nos. | .. | (1 No. double-headed and 1 No. single-headed). |
| Suction adapter .. | 1 No. | .. | |
| Suction spanner .. | 1 No. | 1 No. | |
| Copper strainer .. | 1 No. | 1 No. | |
| Foot valve (gunmetal) .. | 1 No. | 1 No. | |
| Basket strainer .. | 1 No. | 1 No. | |
| $2\frac{1}{2}$-in. i/d flax canvas delivery fire hose .. | Sufficient to suit local conditions with a minimum of 1,200 feet. | | |
| $2\frac{1}{2}$-in. Branch pipes .. | 2 Nos. | 2 Nos. | |
| Branch pipe nozzles : | | | |
| $1\frac{1}{8}''$, $1''$, $\frac{7}{8}''$ .. | One each for larger sizes of trailer fire-engines only. | | |
| $\frac{3}{4}''$ .. | 1 No. | 1 No. | |
| $\frac{5}{8}''$ .. | 2 Nos. | 2 Nos. | |
| $\frac{1}{2}''$ .. | 2 Nos. | 2 Nos. | |
| $\frac{3}{8}''$ .. | 2 Nos. | 2 Nos. | |
| London nozzle .. | 1 No. | 1 No. | For large-size trailer fire-engines. |
| Pouderoux diffuser .. | 1 No. | 1 No. | |
| Portable hand pump with hose .. | 1 No. | 1 No. | |
| Red Hill equipment .. | 1 Set | 1 Set. | |
| Portable canvas dam, 100 gallons capacity .. | 1 No. | 1 No. | |
| Collapsible canvas buckets .. | 3 Nos. | 3 Nos. | |
| Hose clamps .. | 1 No. for every 200 ft. length of delivery hose. | | |
| Telescopic ladder .. | 1 No. | 1 No. | For large towns only. |

| *Description of item of equipment* | *For places with piped water supply* | *For places without piped water supply* | *Remarks* |
|---|---|---|---|
| Bamboo ladder 20 ft. .. | 1 No. | 1 No. | |
| Hook ladder, light .. | 1 No. | 1 No. | |
| Hose-repairing outfit .. | 1 No. | 1 No. | |
| Hose-winding machine .. | 1 No. | 1 No. | |
| Shut-off and control, dividing breeching .. | 1 No. | 1 No. | |
| Collecting breeching .. | 1 No. | 1 No. | |
| Double male instantaneous coupling .. | 1 No. | 1 No. | |
| Double female instantaneous coupling .. | 1 No. | 1 No. | |
| Lifting screw jack (10-ton capacity) .. | 1 No. | 1 No. | |
| Jumping sheet .. | 1 No. | 1 No. | |
| 4′×4′ asbestos blankets .. | 2 Nos. | 2 Nos. | |
| First-Aid medical set .. | 1 No. | 1 No. | |
| Life line 60 ft. .. | 1 No. | 1 No. | |
| Manilla rope 2-in. 100 ft. length | 1 length | 1 length | |
| Manilla rope 2-in. 50 ft. length .. | 1 length | 1 length | |
| Rubber gloves .. | 2 pairs | 2 pairs | For places with electric supply. |
| Heavy axe with handle .. | 1 No. | 1 No. | |
| Pickaxes with handles .. | 2 Nos. | 2 Nos. | |
| *Kassis* or shovels .. | 2 Nos. | 2 Nos. | |
| Crowbar .. | 1 No. | 1 No. | |
| Hand-saw .. | 1 No. | 1 No. | |
| 12″ insulated plier .. | 1 pair | 1 pair | Ditto. |
| Sledge hammer (7 lbs.) with handle | 1 No. | 1 No. | |
| Screw-driver .. | 1 No. | 1 No. | |
| Neon light switching-off hook .. | 1 No. | 1 No. | Ditto. |
| Nozzle spanner .. | 2 Nos. | 2 Nos. | |
| Hose and tool cart .. | 1 No. | 1 No. | |
| Firemen's uniforms with boots, etc. .. | 1 set per Fireman. | | |
| Firemen's belt, pouch, axe, life line and helmet, etc. .. | 1 set per Fireman. | | |
| Thunder whistles .. | 2 Nos. | 2 Nos. | |
| Dark glasses .. | 2 pairs | 2 pairs | |
| Electric torches .. | 2 Nos. | 2 Nos. | |
| Hurricane lamps .. | 2 Nos. | 2 Nos. | |
| Bell siren .. | 1 No. | 1 No. | |
| Hose suspenders .. | 3 Nos. | 3 Nos. | |

| *Description of item of equipment* | *For places with piped water supply* | *For places without piped water supply* | *Remarks* |
|---|---|---|---|
| Spare delivery coupling rubber washers .. | 3 Nos. | 3 Nos. | |
| Box of storm proof maches .. | 2 boxes. | 2 boxes | |
| Lock and chain .. | 1 set. | 1 set. | |

(B) PERSONNEL

The personnel given below is the minimum nucleus establishment required per trailer fire pump and this will need to be considerably supplemented by voluntary workers at the time of an actual fire :

(*i*) Station Officer, who should be a good Mechanic and Driver also .. .. 1 No.

(*ii*) Trailer Fire-Engine Driver .. .. 1 No.

(*iii*) Head Fireman .. .. .. 1 No.

(*iv*) Firemen .. .. .. 6 Nos.

Where there are several trailer units in a Brigade, a Station Officer can control two or more units.

These men should reside at the Fire Station and be available at all times of the day and night and either the Station Officer or the Trailer Fire-Engine Driver should always be present at the Fire Station.

A motor vehicle is required to tow the trailer fire pump and to carry the hoses and equipment as well as the firemen to the scene of the fire. An ordinary, open-body type, light lorry suits admirably for this purpose.

## 11. Acknowledgment

The author takes this opportunity of expressing his greatest gratitude to Mr. D. A. Howell, M. INST. C.E., M.I. MECH. E., Superintending Engineer, Public Health Circle, Punjab, by whose guidance, help and unending patience the author learnt this subject from him and has been able to put this paper before the Punjab Engineering Congress.

## *APPENDIX I*

### PART I

*Tables showing Discharge of Water from plain nozzles of sizes, ranging from ¼-in. to ⅝-in. bore with approximate height and lengths of effective fire streams therefrom for Fire-fighting purposes based on experimental results of Prof. F. M. Dawson, Professor of Hydraulic and Sanitary Engineering, University of Wisconsin, U. S. A.*

NOTE—The effective height and length of a fire stream is the height and length at which the jet starts to lose force necessary for fire-fighting purposes.

| *Bore of nozzle* | *Pressure at nozzle in lbs. per square inch* | *Velocity of discharge in feet per second* | *Discharge in imperial gallons per minute—Coefficient of discharge = 0.97* | *Effective height of vertical fire stream in Feet* | *Effective length of horizontal fire stream in Feet* |
|---|---|---|---|---|---|
| ¼-in. internal diameter | 20 | 55 | 6.7 | 18 | 19 |
| | 30 | 67 | 8.2 | 24 | 26 |
| | 40 | 77 | 9.5 | 29 | 33 |
| | 50 | 86 | 11 | 38 | 36 |
| | 60 | 95 | 12 | 41 | 38 |
| | 70 | 102 | 13 | 43 | 40 |
| | 100 | 122 | 15 | 47 | 43 |
| 5/16-in. internal diameter | 20 | 55 | 11 | 21 | 25 |
| | 30 | 67 | 13 | 28 | 31 |
| | 40 | 77 | 15 | 36 | 36 |
| | 50 | 86 | 17 | 42 | 39 |
| | 60 | 95 | 18 | 47 | 43 |
| | 70 | 102 | 20 | 50 | 46 |
| | 100 | 122 | 24 | 53 | 49 |
| ⅜-in. internal diameter | 20 | 55 | 15 | 26 | 28 |
| | 30 | 67 | 19 | 31 | 33 |
| | 40 | 77 | 21 | 39 | 42 |
| | 50 | 86 | 24 | 45 | 44 |
| | 60 | 95 | 26 | 51 | 48 |
| | 70 | 102 | 28 | 56 | 51 |
| | 100 | 122 | 34 | 58 | 52 |

| *Bore of nozzle* | *Pressure at nozzle in lbs. per square inch.* | *Velocity of discharge in feet per second* | *Discharge in imperial gallons per minute—Coefficient of discharge = 0.97* | *Effective height of vertical fire stream in Feet* | *Effective length of horizontal fire stream in Feet* |
|---|---|---|---|---|---|
| 7/16-in. internal diameter | 20 | 55 | 20 | 29 | 30 |
| | 30 | 67 | 25 | 36 | 37 |
| | 40 | 77 | 29 | 42 | 43 |
| | 50 | 86 | 33 | 48 | 48 |
| | 60 | 95 | 36 | 56 | 49 |
| | 70 | 102 | 39 | 59 | 55 |
| | 100 | 122 | 46 | 64 | 58 |
| ½-in. internal diameter | 20 | 55 | 27 | 33 | 34 |
| | 30 | 67 | 33 | 38 | 40 |
| | 40 | 77 | 38 | 46 | 44 |
| | 50 | 86 | 43 | 52 | 51 |
| | 60 | 95 | 47 | 59 | 57 |
| | 70 | 102 | 51 | 66 | 59 |
| | 100 | 122 | 60 | 72 | 63 |
| 9/16-in. internal diameter | 20 | 55 | 34 | 34 | 35 |
| | 30 | 67 | 42 | 45 | 43 |
| | 40 | 77 | 48 | 50 | 47 |
| | 50 | 86 | 54 | 58 | 53 |
| | 60 | 95 | 59 | 65 | 59 |
| | 70 | 102 | 64 | 71 | 63 |
| | 100 | 122 | 76 | 76 | 66 |
| ⅝-in. internal diameter | 20 | 55 | 42 | 35 | 37 |
| | 30 | 67 | 52 | 48 | 46 |
| | 40 | 77 | 60 | 54 | 52 |
| | 50 | 86 | 67 | 61 | 59 |
| | 60 | 95 | 73 | 72 | 65 |
| | 70 | 102 | 79 | 77 | 72 |
| | 100 | 122 | 95 | 84 | 76 |

## APPENDIX I

### PART II

*Tables showing discharge of Water from plain nozzles of sizes ranging from ¾-in. to 1⅛-in. bore with approximate heights and lengths of effective fire streams therefrom for Fire-fighting purposes based on results of experiments made in U. S. A. by Mr. J. R. Freeman, C. E.*

NOTE—The effective height and length of a fire stream is the height and length at which the jet starts to lose force necessary for fire-fighting purposes.

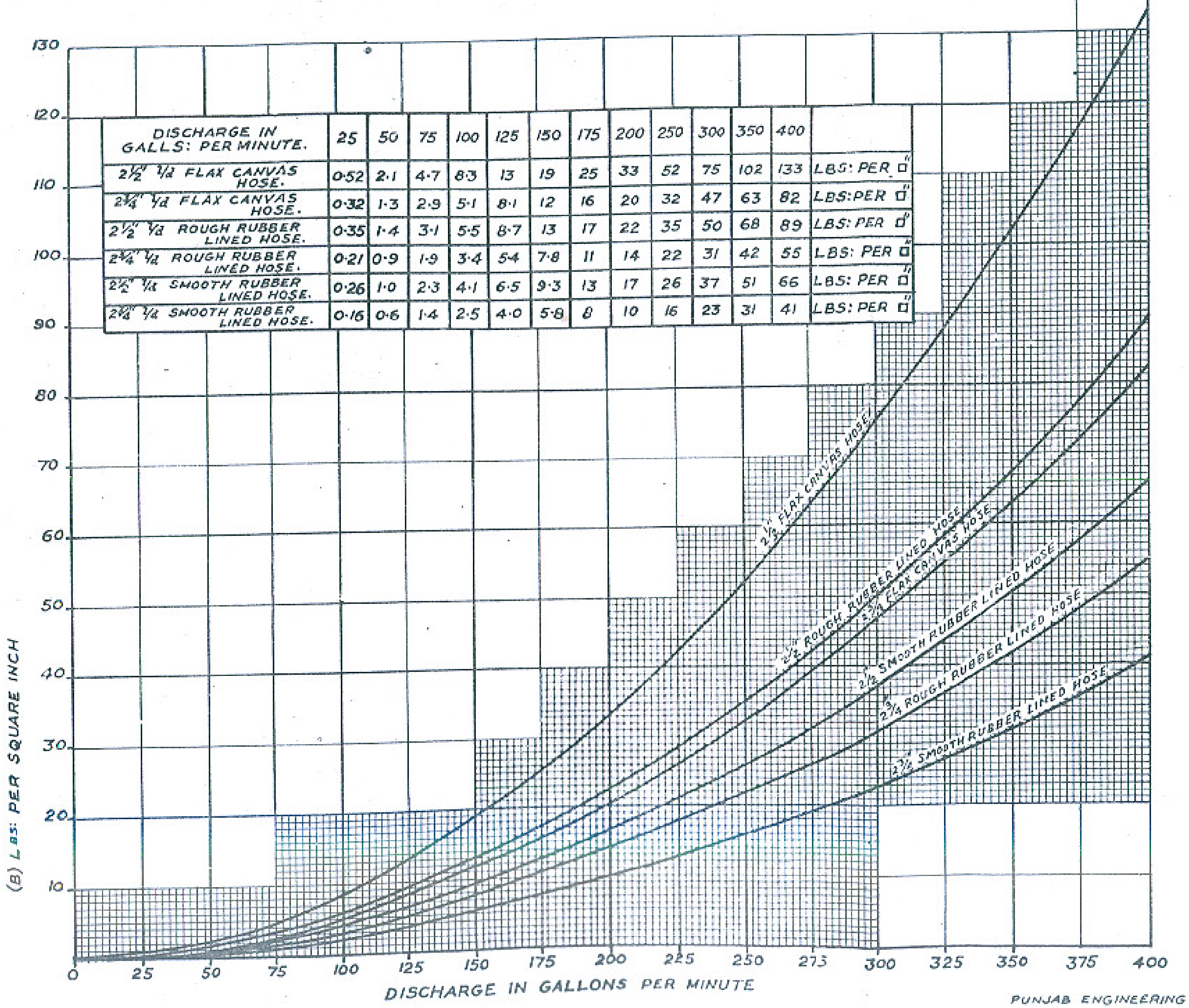
| *Bore of nozzle* | *Pressure at nozzle in lbs. per square inch* | *Velocity of discharge in feet per second* | *Discharge in imperial gallons per minute—Coefficient of discharge =0.97* | *Effective height of vertical fire stream in Feet* | *Effective length of horizontal fire stream in Feet* |
|---|---|---|---|---|---|
| ¾-in. internal diameter | 20 | 55 | 61 | 33 | 29 |
| | 25 | 61 | 68 | 41 | 33 |
| | 30 | 67 | 74 | 48 | 37 |
| | 35 | 72 | 81 | 55 | 41 |
| | 40 | 77 | 86 | 60 | 44 |
| | 45 | 82 | 91 | 64 | 47 |
| | 50 | 86 | 96 | 67 | 50 |
| | 60 | 95 | 105 | 72 | 54 |
| | 70 | 102 | 114 | 76 | 58 |
| | 80 | 109 | 121 | 79 | 62 |
| | 90 | 116 | 129 | 81 | 65 |
| | 100 | 122 | 136 | 83 | 68 |
| ⅞-in. internal diameter | 20 | 55 | 82 | 34 | 33 |
| | 25 | 61 | 92 | 42 | 38 |
| | 30 | 67 | 101 | 49 | 42 |
| | 35 | 72 | 109 | 56 | 46 |
| | 40 | 77 | 117 | 62 | 49 |
| | 45 | 82 | 124 | 67 | 52 |
| | 50 | 86 | 131 | 71 | 55 |
| | 60 | 95 | 143 | 77 | 61 |
| | 70 | 102 | 154 | 81 | 66 |
| | 80 | 109 | 166 | 85 | 70 |
| | 90 | 116 | 175 | 88 | 74 |
| | 100 | 122 | 185 | 90 | 76 |

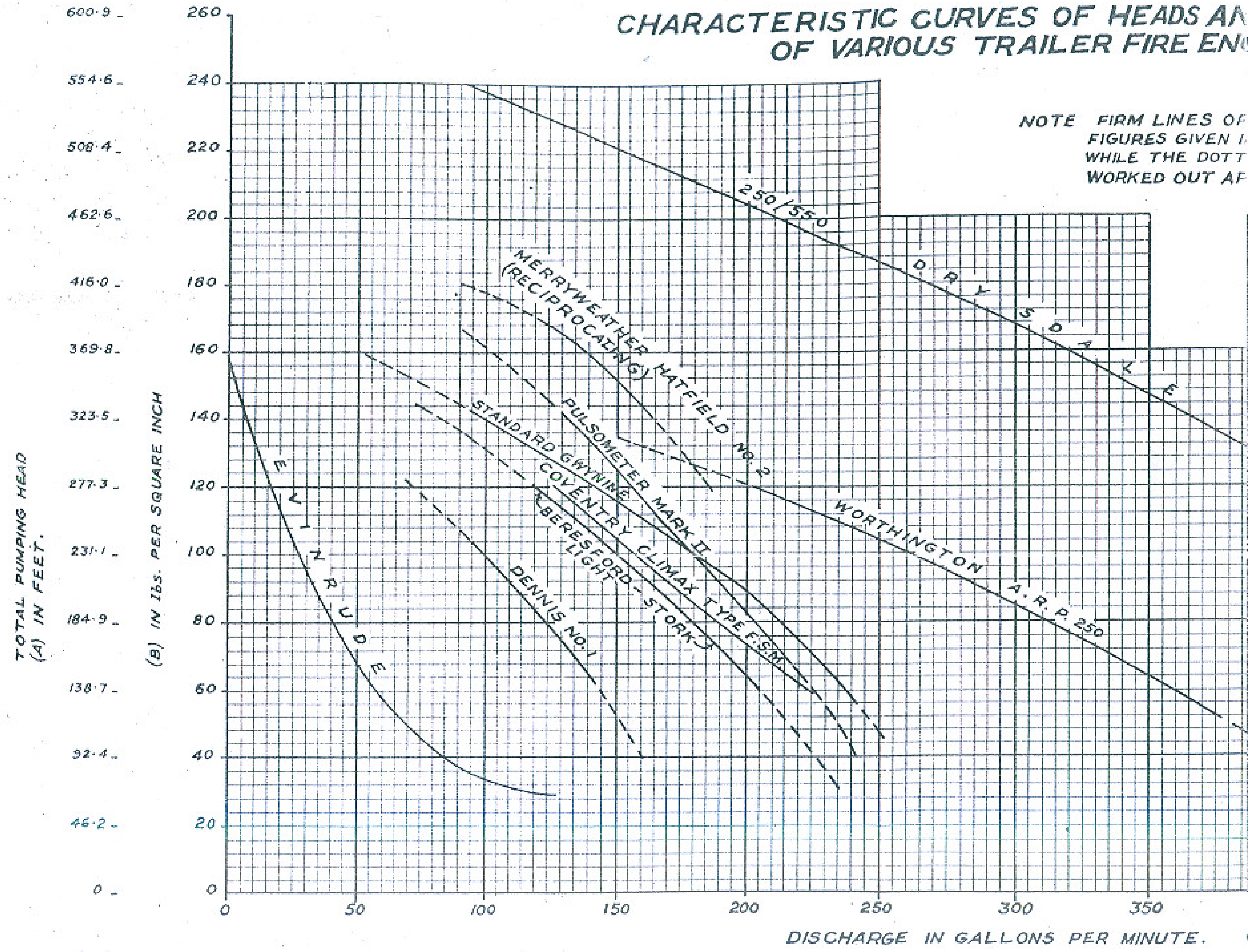
| Bore of nozzle | Pressure at nozzle in lbs. per square inch | Velocity of discharge in feet per second | Discharge in imperial gallons per minute—Coefficient of discharge = 0.97. | Effective height of vertical fire stream in Feet | Effective length of horizontal fire stream in Feet |
|---|---|---|---|---|---|
| 1-in. internal diameter | 20 | 55 | 108 | 35 | 37 |
| | 25 | 61 | 120 | 43 | 42 |
| | 30 | 67 | 133 | 51 | 47 |
| | 35 | 72 | 143 | 58 | 51 |
| | 40 | 77 | 153 | 64 | 55 |
| | 45 | 82 | 162 | 69 | 58 |
| | 50 | 86 | 171 | 73 | 61 |
| | 60 | 95 | 187 | 79 | 67 |
| | 70 | 102 | 202 | 85 | 72 |
| | 80 | 109 | 216 | 89 | 76 |
| | 90 | 116 | 229 | 92 | 80 |
| | 100 | 122 | 242 | 96 | 83 |
| $1\frac{1}{8}$-in. internal diameter | 20 | 55 | 137 | 36 | 38 |
| | 25 | 61 | 153 | 44 | 44 |
| | 30 | 67 | 167 | 52 | 50 |
| | 35 | 72 | 181 | 59 | 54 |
| | 40 | 77 | 193 | 65 | 59 |
| | 45 | 82 | 204 | 70 | 63 |
| | 50 | 86 | 216 | 75 | 66 |
| | 60 | 95 | 237 | 83 | 72 |
| | 70 | 102 | 256 | 88 | 77 |
| | 80 | 109 | 273 | 92 | 81 |
| | 90 | 116 | 290 | 96 | 85 |
| | 100 | 122 | 305 | 99 | 89 |

| Bore of nozzle | Pressure at nozzle in lbs. per square inch | Velocity of discharge in feet per second | Discharge in imperial gallons per minute—Coefficient of discharge = 0.97 | Effective height of vertical fire stream in Feet | Effective length of horizontal fire stream in Feet |
|---|---|---|---|---|---|
| $1\frac{1}{4}$-in. internal diameter | 20 | 55 | 169 | 37 | 40 |
| | 25 | 61 | 189 | 46 | 47 |
| | 30 | 67 | 207 | 53 | 54 |
| | 35 | 72 | 224 | 60 | 59 |
| | 40 | 77 | 239 | 67 | 63 |
| | 45 | 82 | 253 | 72 | 67 |
| | 50 | 86 | 267 | 77 | 70 |
| | 60 | 95 | 292 | 85 | 76 |
| | 70 | 102 | 316 | 91 | 81 |
| | 80 | 109 | 338 | 95 | 85 |
| | 90 | 116 | 358 | 99 | 90 |
| | 100 | 122 | 377 | 101 | 93 |
| $1\frac{3}{8}$-in. internal diameter | 20 | 55 | 204 | 38 | 42 |
| | 25 | 61 | 229 | 47 | 49 |
| | 30 | 67 | 250 | 55 | 56 |
| | 35 | 72 | 270 | 62 | 62 |
| | 40 | 77 | 287 | 69 | 66 |
| | 45 | 82 | 306 | 74 | 70 |
| | 50 | 86 | 322 | 79 | 73 |
| | 60 | 95 | 354 | 87 | 79 |
| | 70 | 102 | 382 | 92 | 84 |
| | 80 | 109 | 408 | 97 | 88 |
| | 90 | 116 | 433 | 100 | 92 |
| | 100 | 122 | 457 | 103 | 96 |

# LOSS OF HEAD IN LBS: PER SQUARE INCH DUE TO FRICTION IN PUMPING THROUGH 100 FEET OF FIRE HOSE OF VARIOUS TYPES AND BORES.

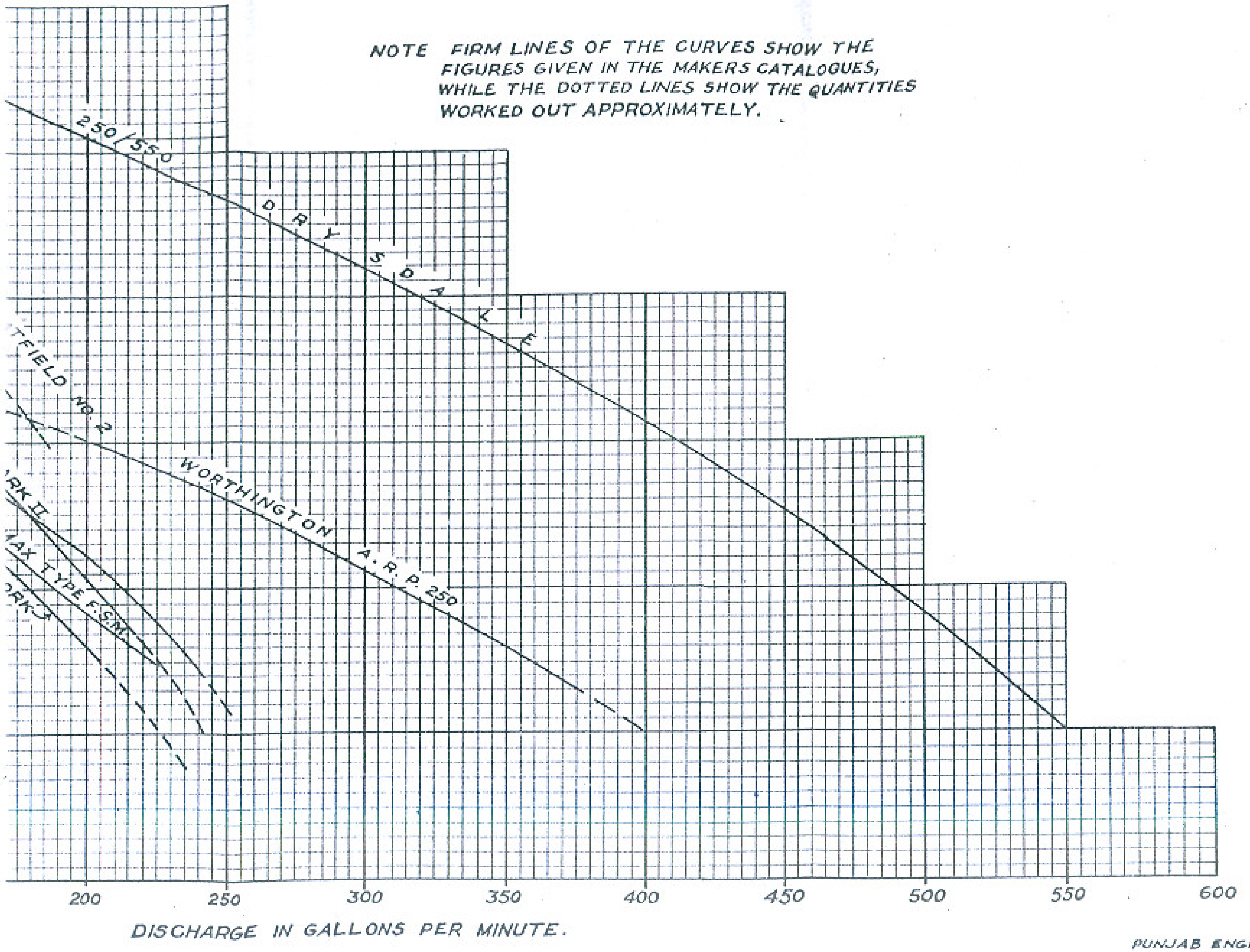
| DISCHARGE IN GALLS: PER MINUTE. | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 250 | 300 | 350 | 400 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2½" ½ FLAX CANVAS HOSE. | 0·52 | 2·1 | 4·7 | 8·3 | 13 | 19 | 25 | 33 | 52 | 75 | 102 | 133 | LBS: PER □" |
| 2¾" ½ FLAX CANVAS HOSE. | 0·32 | 1·3 | 2·9 | 5·1 | 8·1 | 12 | 16 | 20 | 32 | 47 | 63 | 82 | LBS: PER □" |
| 2½" ½ ROUGH RUBBER LINED HOSE. | 0·35 | 1·4 | 3·1 | 5·5 | 8·7 | 13 | 17 | 22 | 35 | 50 | 68 | 89 | LBS: PER □" |
| 2¾" ½ ROUGH RUBBER LINED HOSE. | 0·21 | 0·9 | 1·9 | 3·4 | 5·4 | 7·8 | 11 | 14 | 22 | 31 | 42 | 55 | LBS: PER □" |
| 2½" ¼ SMOOTH RUBBER LINED HOSE. | 0·26 | 1·0 | 2·3 | 4·1 | 6·5 | 9·3 | 13 | 17 | 26 | 37 | 51 | 66 | LBS: PER □" |
| 2¾" ¼ SMOOTH RUBBER LINED HOSE. | 0·16 | 0·6 | 1·4 | 2·5 | 4·0 | 5·8 | 8 | 10 | 16 | 23 | 31 | 41 | LBS: PER □" |





CHARACTERISTIC CURVES OF HEADS AN
OF VARIOUS TRAILER FIRE EN
NOTE FIRM LINES OF
FIGURES GIVEN I
WHILE THE DOTT
WORKED OUT AF
TOTAL PUMPING HEAD
(A) IN FEET.
(B) IN lbs. PER SQUARE INCH
600·9
554·6
508·4
462·6
416·0
369·8
323·5
277·3
231·1
184·9
138·7
92·4
46·2
0
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
DISCHARGE IN GALLONS PER MINUTE.
250/550
DRYSDALE
MERRYWEATHER
(RECIPROCATING)
HATFIELD No. 2
PULSOMETER MARK II
STANDARD GWYNNE
COVENTRY CLIMAX TYPE F.S.M.
BERESFORD - STORK
LIGHT
DENNIS No. 1
EVINRUDE
WORTHINGTON
A.R.P. 250

# ARACTERISTIC CURVES OF HEADS AND DISCHARGES OF VARIOUS TRAILER FIRE ENGINES.



# SLUICE VALVES

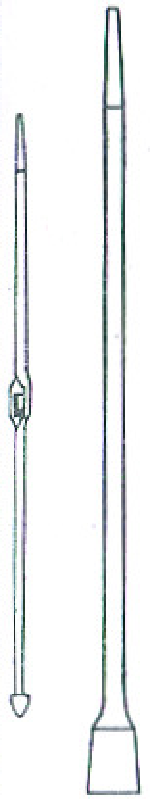


FIG: 3. SLUICE VALVE KEY.

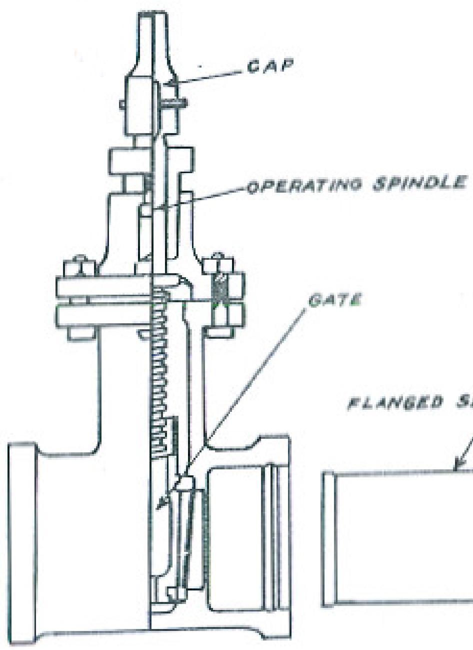



FIG: 1. DOUBLE SOCKETED SLUICE VALVE.

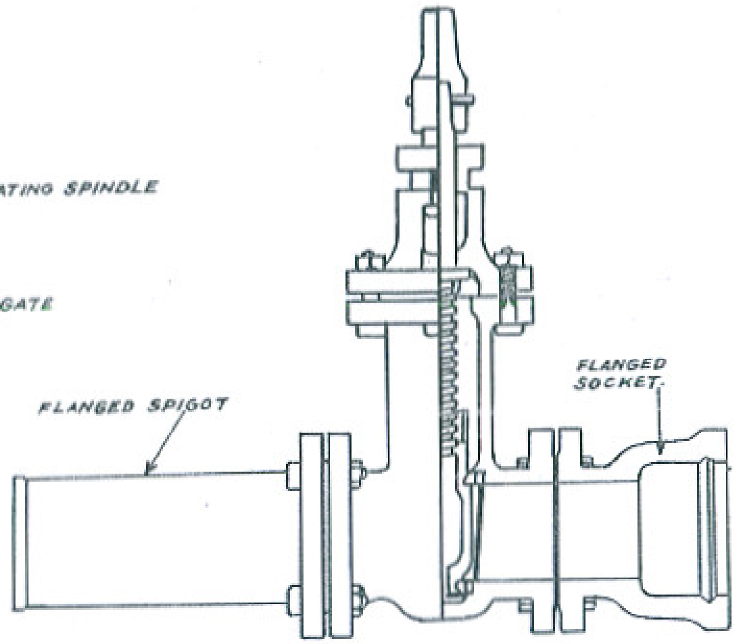



FIG: 2. DOUBLE FLANGED SLUICE VALVE.

FIG: 4. SLUICE VALVE KEY.

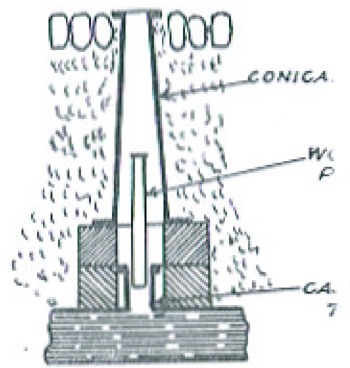



FIG: 6. PLUG IN POSIT.

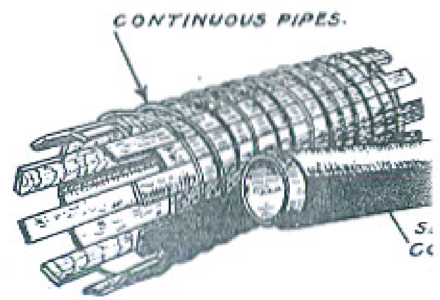



FIG: 5. WOODEN PIPES.