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INVESTIGATION INTO THE PROCESSES GOVERNING THE OPERATION AND DISCHARGE OF FIRE EXTINGUISHERS

by

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SUMMARY

To make an assessment of the design, performance and safety in use of fire extinguishers which are submitted for approval, it was necessary to obtain a picture of the processes governing the operation and discharge of extinguishers of various types.

KEYWORDS: Extinguisher (hand operated)

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
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INTRODUCTION

In normal tests on fire extinguishers pressure measurements are made by the use of simple Bourdon type pressure gauges. These however do not record the transient peak pressures that are developed and therefore no knowledge was available on the effects of design features of various types of extinguishers.

It was therefore decided to carry out some pressure measurements using a recording oscilloscope with a coupled pressure transducer to measure the actual peak pressures developed.

TYPES OF EXTINGUISHERS INVESTIGATED

Seven common types of extinguisher, each varying in the type of charge or in the method of operation, were selected for investigation.

1. SODA ACID (turnover type)

This type is operated by inverting the extinguisher whereby sulphuric acid is spilled from a bottle held in a cage in the neck of the extinguisher to mix with a sodium bicarbonate and water solution in the body. The chemical reaction from the combined acid and alkali solutions generates a pressure in the extinguisher which discharges the now neutralized solution through a nozzle in the inverted dome or in the cap.

2. SODA ACID (plunger type)

This type is operated in the upright position by striking a plunger which breaks a sealed glass bottle containing sulphuric acid. The resultant reaction, as with Type 1, discharges the solution by way of a discharge tube and nozzle in the dome or in the cap.

This type of extinguisher is preferable to the turnover type owing to the better mixing obtained of the two solutions and the unlikely possibility of discharging concentrated sulphuric acid in the initial stages of discharge which is possible with the turnover type due to the proximity of the acid bottle to the discharge outlet.

3. FOAM CHEMICAL (turnover type)

An extinguisher of this type is operated by inverting, or by releasing or piercing a sealing device and inverting, allowing an acid salt solution in an inner container to mix with a sodium bicarbonate solution containing a liquorice or other stabilizer in the outer container.

The resultant reaction from the mixing of the two solutions discharges the liquid in the form of foam.

4. FOAM (gas pressure type)

It is operated in the upright position by striking a plunger having a pointed end or piercer. This pierces a diaphragm in a high pressure carbon dioxide cartridge attached to the interior of the cap, thereby releasing gas into the body which contains a hydrolised protein solution.

The resultant pressure built up in the body discharges the solution through a discharge tube hose and foam branchpipe where air at atmospheric pressure is induced causing the liquid to form foam.

This type of extinguisher which does not rely on the mixing of two liquids is preferable to the chemical foam type because of a more consistent foam being produced throughout the discharge.

5. WATER TYPE (gas pressure)

The operation of this type is similar to Type 4 except that the body contains water with possibly a corrosion inhibitor or an antifreeze solution, the final discharge being through a nozzle instead of a branchpipe.

6. WATER TYPE (gas pressure) WITH METERED GAS DISCHARGE

The operation and contents of this extinguisher are similar to Type 5 except for the CO_2 cartridge seal. The seal consists of a brass cap with a hollow projecting spigot which, when broken by the action of the plunger, allows the gas to escape through a small orifice.

This type of metered release is preferable to the pierced diaphragm which can vary in the size of orifice and rate of release of gas, depending on the severity of the blow struck on the operating plunger. The shock to the extinguisher body is also less severe with the metered discharge because of the slower release of gas.

7. DRY POWDER (gas cartridge type)

The operation is similar to Type 4 but with the control valve closed. With the release of gas and on opening the control valve the powder becomes fluidized during the final discharge through the discharge tube and temporary shut-off control valve.

One extinguisher of each of the above types was used in the investigation, Types 1-6 were each rated at 9.1 l (2 gal) capacity and Type 7, 9.1 kg (20 lb) in weight.

Extinguishers Types 1, 2, 5 and 6 were for use on Class A fires of common combustibles such as wood, paper etc. Types 3, 4 and 7 were for use on Class B fires of liquids such as oil, petrol and fats. Type 7 was also for use on Class C fires in electrical equipment.

MEASURING EQUIPMENT

The following items were used for the fabrication of the measuring equipment.

1. Transducer manufactured by Consolidated Electrodynamics, Woking, Surrey. Type 4-326-L100. Serial No.L7565. Range 0-35 kgf/cm^2 (0-500 lbf/in^2).

2. 10 volt DC battery supply and transducer balancing network.

3. Storage oscilloscope manufactured by Tektronix Ltd. Type 564 basic oscilloscope, Type 2B67 time base Type 2A63 differential amplifier.

4. Spring balance 0-23 kg (0-50 lb) manufactured by Salter. Type 23500.

METHOD OF MEASUREMENT

CLOSED PRESSURE

One each of seven types of extinguisher with the nozzles blocked was charged in accordance with the manufacturers' instructions and the pressure transducer was attached to the cap. The transducer output connections were taken from the balancing network to the oscilloscope and the controls positioned to give a trace.

The appropriate operating procedure was initiated for each of the extinguishers in turn and coincidentally the oscilloscope was operated producing the traces relating pressure and time.

DISCHARGE TIME AND PRESSURE

The discharge time and the pressure for each extinguisher were determined, as for closed pressure measurements, except that the extinguisher was allowed to discharge the contents through an open nozzle or a control valve. The average rate of discharge for each extinguisher was calculated by dividing its capacity by the actual time of discharge.

DISCHARGE RATE

Concurrently with discharge measurements, readings were taken at intervals of the loss in weight of the extinguishant during discharge.

TEST RESULTS

The results of various tests are summarized in Table 1 and shown in Figures 1 to 7.

TABLE 1

Type	Closed pressure		Discharge		
	Maximum pressure developed kgf/cm^2 (lbf/in^2)	Time to reach maximum pressure (s)	Maximum pressure during discharge kgf/cm^2 (lbg/in^2)	Time of discharge (s)	Average rate of discharge kg/s (lb/s)
1	9.7 (138)	20	5.6 (80)	120	0.075 (0.166)
2	8.4 (120)	60	4.9 (70)	150	0.06 (0.133)
3	14 (200)	300	2.1 (30)	60	0.15 (0.33)
4	17.5 (250)	0.8	14.7 (208)	50	0.18 (0.4)
5	11.9 (170)	0.8	10.5 (150)	80	0.11 (0.25)
6	14 (200)	2.2	10.5 (150)	50	0.15 (0.33)
7	16.1 (230)	5	17.4 (248)	15	0.6 (1.33)

EXAMINATION OF RESULTS

TYPE 1. SODA ACID (turnover type)

On operation with the nozzle blocked, Fig.1A, the pressure slowly increased to 6.9 kgf/cm^2 (98 lbf/in^2) during the first 12 seconds then suddenly jumped to 9.7 kgf/cm^2 (138 lbf/in^2) and settled to 7.1 kgf/cm^2 (102 lbf/in^2) during the next 4 seconds. This was caused by the glass bottle breaking and suddenly releasing the remainder of the acid contents causing a fierce reaction and surge of pressure.

During discharge, Fig.1B, the pressure gradually built up to a maximum of 5.6 kgf/cm^2 (80 lbf/in^2) in the first 40 seconds then gradually decreased to zero during the remainder of the 175 seconds discharge.

The rate of discharge, Fig.1C, which was low for the first 25 seconds suddenly increased during the next 15 seconds to a maximum of 0.14 kg/s (0.3 lb/s) then decreased in steps to zero at 120 seconds. The average rate of discharge was 0.075 kg/s (0.166 lb/s).

No dangerous transient peak pressures were recorded during operation although the breaking of an acid bottle during the early stages of discharge could cause a surge of pressure and also a discharge of acid due to the close proximity of the acid bottle to the nozzle.

TYPE 2. SODA ACID (plunger type)

During operation with the nozzle blocked, Fig.2A, there was an increase in pressure to 5.9 kgf/cm^2 (85 lbf/in^2) during the first 10 seconds then a gradual increase to 7.7 kgf/cm^2 (110 lbf/in^2). At 60 seconds the pressure jumped to a maximum of 8.4 kgf/cm^2 (120 lbf/in^2) probably due to some acid trapped in the bottom of the broken bottle becoming reactive.

During discharge, Fig.2B, the pressure built up to a maximum of 4.9 kgf/cm^2 (70 lbf/in^2) during the first 5 seconds dropping to 1.8 kgf/cm^2 (25 lbf/in^2) at 30 seconds then gradually to zero during the remainder of the 180 seconds discharge.

The rate of discharge, Fig.2C, was high for the first 25 seconds due to the rapid absorption of the acid dropping from the top to the bottom of the extinguisher, but gradually decreased during the remainder of the discharge. No dangerous transient peak pressures were recorded during the discharge which reached a peak rate of 0.14 kg/s (0.3 lb/s) almost immediately and gradually decreased to zero after 150 seconds. The average rate of discharge was 0.6 kg/s (1.33 lb/s).

There is little risk of concentrated acid being discharged from this type of extinguisher because of the more thorough mixing of the solutions during initiation of the charge. The rate of pressure rise will depend on how quickly the acid is released from the bottle into the alkali solution and will in turn depend on whether there is complete or only partial fragmentation of the glass bottle when the plunger is operated.

TYPE 3. FOAM, CHEMICAL (turnover type)

During operation with the nozzle blocked, Fig.3A, pressure rose slowly during a period of 5 minutes to a maximum of 14 kgf/cm^2 (200 lbf/in^2).

During discharge, Fig.3B, the pressure rose to a peak of 2.1 kgf/cm^2 (30 lbf/in^2) during the first 12 seconds then gradually fell to zero during the remainder of the 50 seconds discharge.

The rate of discharge, Fig.3C, increased during the first 10 seconds from 0.09 to 0.3 kg/s (0.2 to 0.65 lb/s) then fell sharply to 0.14 kg/s (0.3 lb/s) at 20 seconds then gradually to zero at 60 seconds. The average rate of discharge was 0.15 kg/s (0.33 lb/s).

The low pressure developed during discharge when compared with the comparatively high pressure developed in the closed pressure test would point to slow inefficient mixing of the two solutions. Agitation of the extinguisher during discharge or an improved inner container which would allow the solutions to mix more quickly should improve the quality of the foam produced.

TYPE 4. FOAM (gas pressure type)

During operation with the nozzle blocked, Fig.4A, the pressure reached a maximum of 17.5 kgf/cm^2 (250 lbf/in^2) in 0.8 seconds and remained constant.

During discharge, Fig.4B, the pressure rose to a peak of 14.7 kgf/cm^2 (208 lbf/in^2) in one second, dropped to 7 kgf/cm^2 (100 lbf/in^2) at 25 seconds and then gradually to zero during the remainder of the 100 second discharge.

The rate of discharge, Fig.4C, dropped during the first 25 seconds from 0.26 kg/s (0.6 lb/s) to 0.2 kg/s (0.45 lb/s) remained fairly linear up to 40 seconds then dropped rapidly to zero at 50 seconds. The average rate of discharge was 0.18 kg/s (0.4 lb/s).

This type of extinguisher was efficient in operation and maintained a very even rate of discharge throughout its operation.

TYPE 5. WATER TYPE (gas pressure)

During operation with the nozzle blocked, Fig.5A, there was a sudden increase in pressure to 5.6 kgf/cm^2 (80 lbf/in^2) in 0.05 seconds then through a series of small oscillations which damped out to reach a maximum pressure of 12.3 kgf/cm^2 (175 lbf/in^2) at 0.8 seconds.

During discharge, Fig.5B, the pressure rose to a peak of 10.5 kgf/cm^2 (150 lbf/in^2) in 1.5 seconds, dropping to 5.6 kgf/cm^2 (80 lbf/in^2) in 10 seconds, then gradually to zero during the 80 seconds discharge.

The rate of discharge, Fig.5C, dropped during the first 20 seconds from 0.18 kg/s (0.4 lb/s) to 0.11 kg/s (0.25 lb/s), remained fairly linear up to 60 seconds then dropped steadily to zero at 80 seconds. The average rate of discharge was 0.11 kg/s (0.25 lb/s).

TYPE 6. WATER TYPE (gas pressure) WITH METERED DISCHARGE

When operated with the nozzle blocked, Fig.6A, the pressure reached its maximum of 14 kgf/cm^2 (200 lbf/in^2) in 2.2 seconds.

During discharge, Fig.6B, the pressure rose to 10.5 kgf/cm^2 (150 lbf/in^2) in $2\frac{1}{2}$ seconds then dropped sharply to 7 kgf/cm^2 (100 lbf/in^2) at 10 seconds, then gradually to zero during 80 seconds discharge.

The rate of discharge, Fig.6C, dropped steadily from 0.25 kg/s (0.55 lb/s) to 0.14 kg/s (0.3 lb/s) at 30 seconds and continued until 50 seconds when the rate dropped to zero at 60 seconds. The average rate of discharge was 0.15 kg/s (0.33 lb/s).

The metered charge, Type 6, required little physical effort to operate compared with the unmetered piercer, Type 5, otherwise there was little difference in performance between the two types of extinguishers.

TYPE 7. DRY POWDER (gas cartridge type)

When operated with the control valve closed, Fig.7A, the pressure rose steadily to 16.1 kgf/cm^2 (230 lbf/in^2) over a period of 4 seconds, thereafter remaining constant.

During discharge, Fig.7B, the pressure rose to 17.2 kgf/cm^2 (246 lbf/in^2) in 4 seconds before opening the control valve then dropped steadily to zero during 21 seconds discharge.

The rate of discharge, Fig.7C, dropped from 1.1 kg/s (2.35 lb/s) to 0.86 kg/s (1.9 lb/s) in 2 seconds, continued at an even rate until 8 seconds then dropped steadily to zero at 15 seconds. The average rate of discharge was 0.6 kg/s (1.33 lb/s).

CONCLUSIONS

From the curves Figs 1A to 7A there appeared to be no excessive transient high pressures developed in any of the extinguishers examined.

The closed pressure operation was obviously more severe than with an open nozzle and on the gas pressure water and foam extinguishers than with the chemical types where there was a slow generation of pressure. Conditions were also less severe for the dry powder type owing to the cushioning effect of the powder.

The worst case recorded was on Type 5 which indicates a pressure increase rate of 112 $kgf/cm^2/s$ (1600 $lbf/in^2/s$) maintained for 50 milliseconds and reaching a pressure of 5.6 kgf/cm^2 (80 lbf/in^2). Full generation of pressure on the chemical foam extinguisher can take up to 5 minutes and the quality of the foam produced would be improved by quicker and more effective mixing of the two solutions by improving the design of the inner container. Dangerous conditions could also arise with chemical type extinguishers with a blocked nozzle using charges which had not been checked in the design stage against the maximum pressure developed in the extinguisher.

Soda acid extinguishers of the plunger type were shown to have better mixing properties than the turnover type. When inverted there is a risk that in the initial stages of discharge some concentrated acid may be discharged owing to the close proximity of the acid bottle to the discharge nozzle.

There was little difference between the performance of the unmetered and metered CO_2 charges for gas operated extinguishers although the metered charge had a slight advantage because of easier operation and a slightly longer charging period. The metered charge, sometimes thought to maintain a constant pressure during discharge due to the slow release of gas from the cartridge, in fact releases the full gas charge into the extinguisher in about 2 seconds.

The dry powder extinguisher with a gas charging period of about 5 seconds is probably the safest to use of all the extinguishers examined. This is due to the slow diffusion of the gas through the powder which will provide a cushioning effect even when the extinguisher is overfilled.

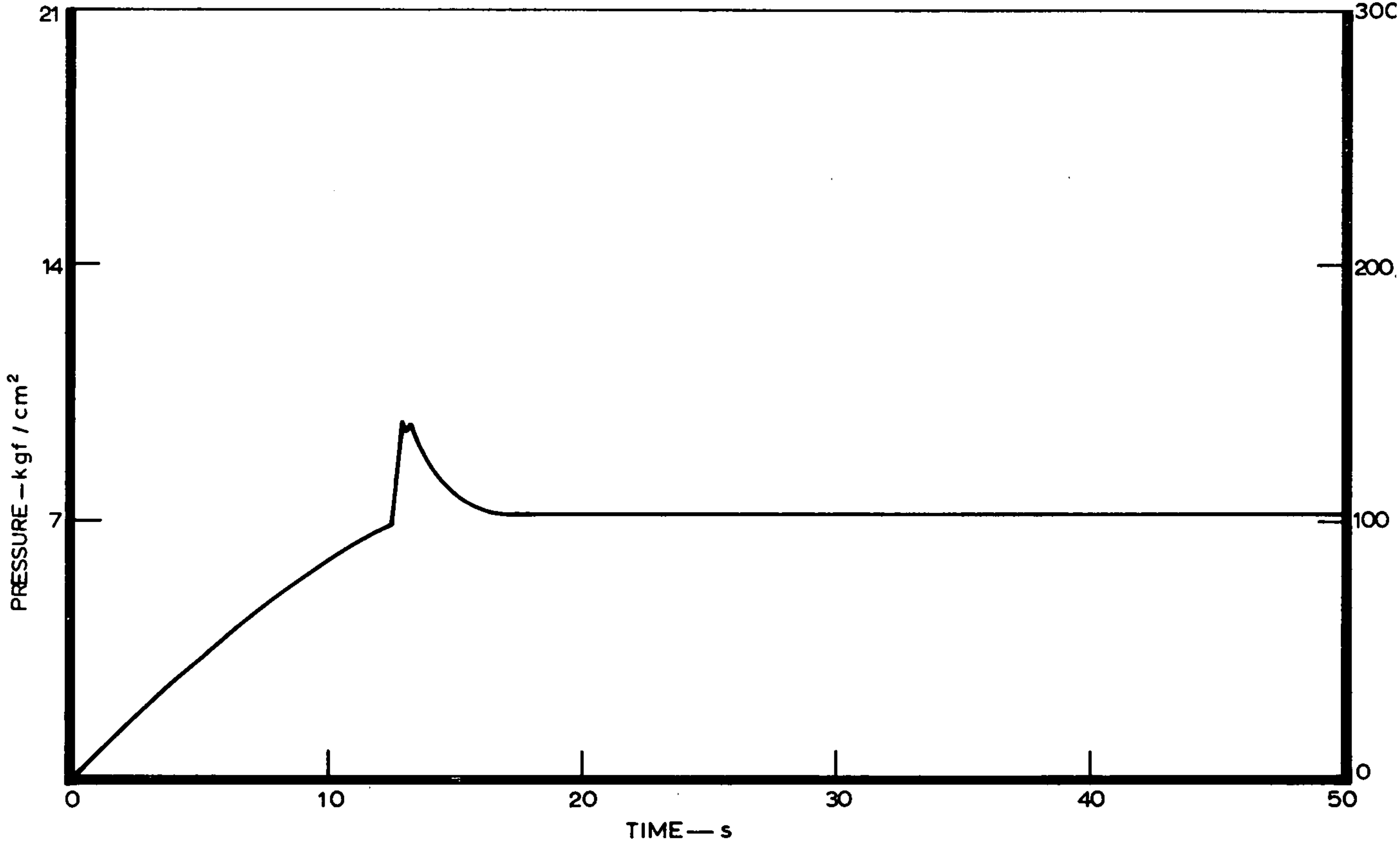

FIG. 1a. TYPE 1 — 9·1 - LITRE (2 - GALLON) SODA ACID (TURNOVER TYPE) CLOSED PRESSURE

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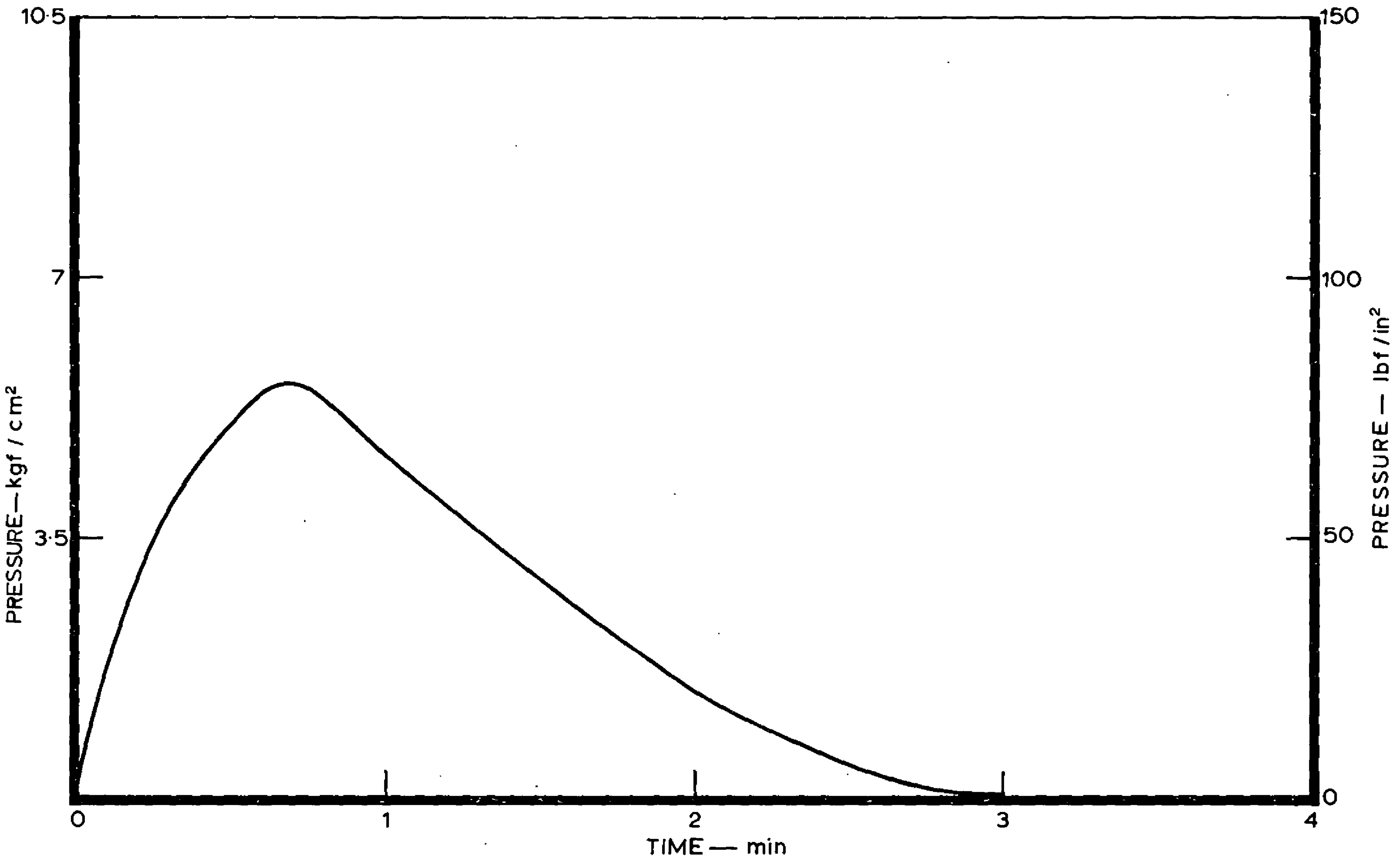

FIG.1b. TYPE 1—9·1-LITRE (2-GALLON) SODA ACID (TURNOVER TYPE) DISCHARGE

/8960 F.R. 767.

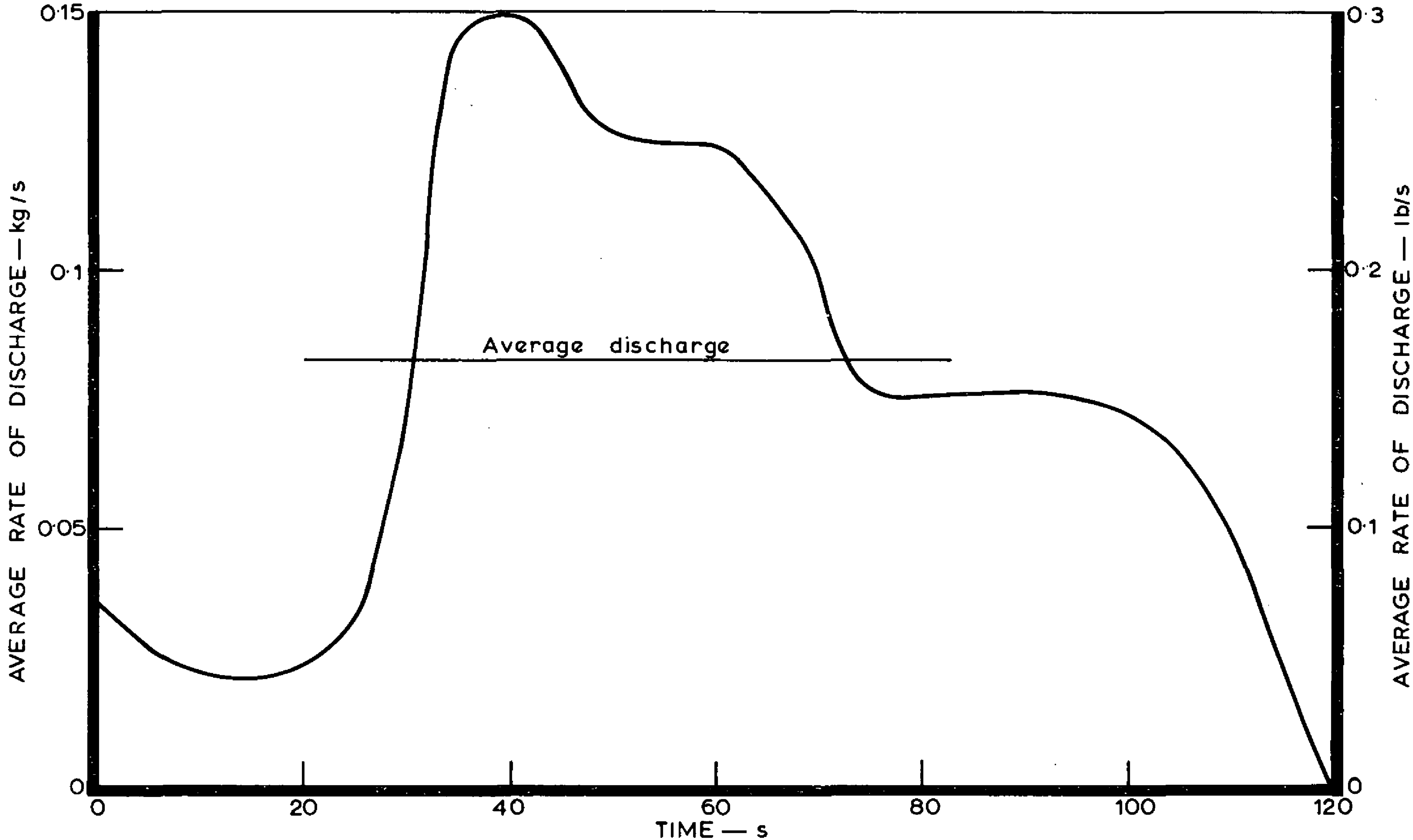

FIG. 1c. TYPE 1—9·1- LITRE (2-GALLON) SODA ACID (TURNOVER TYPE) RATE OF DISCHARGE

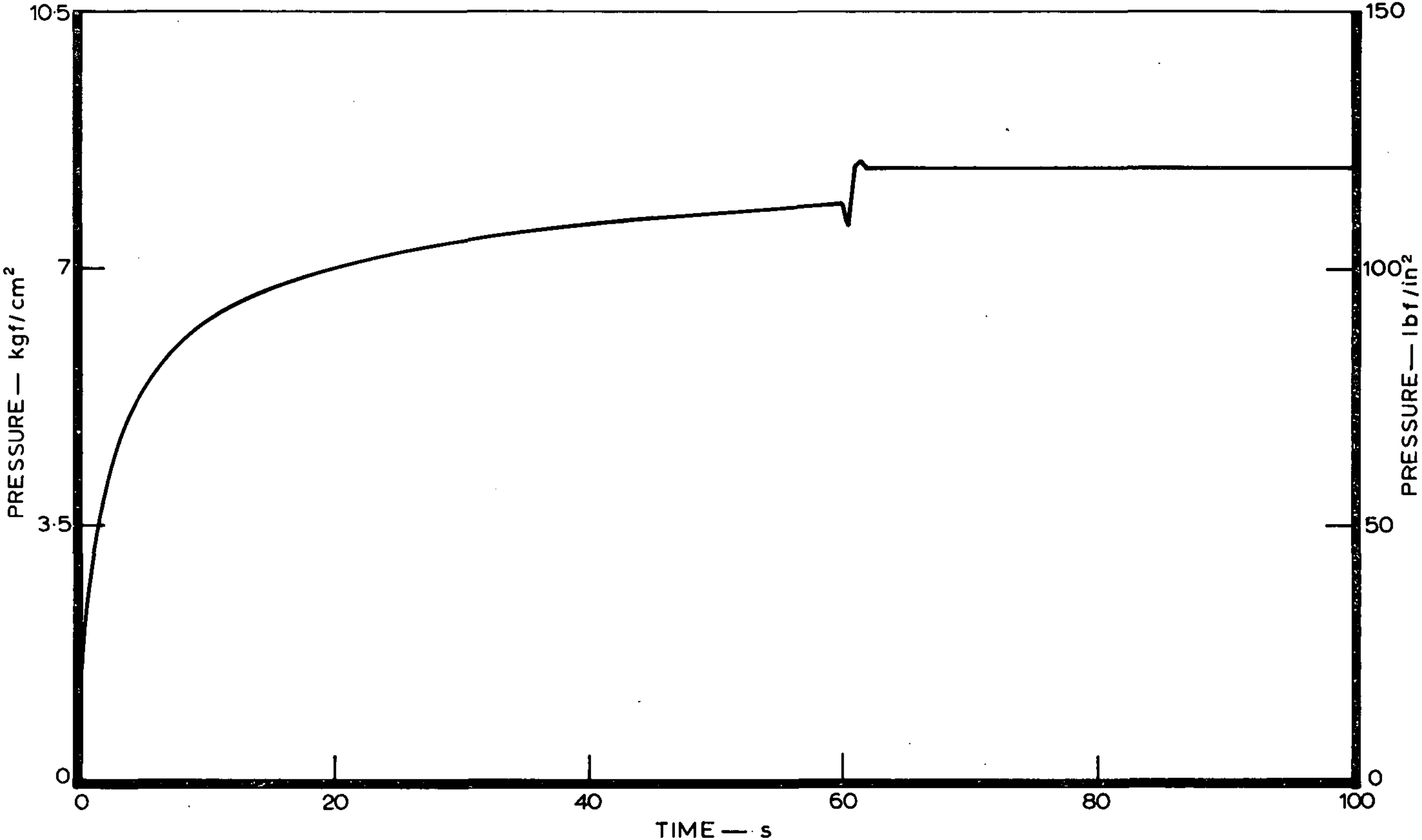

FIG. 2a. TYPE 2—9·1-LITRE (2-GALLON) SODA ACID (PLUNGER TYPE) CLOSED PRESSURE

1/8962 F.R. 767

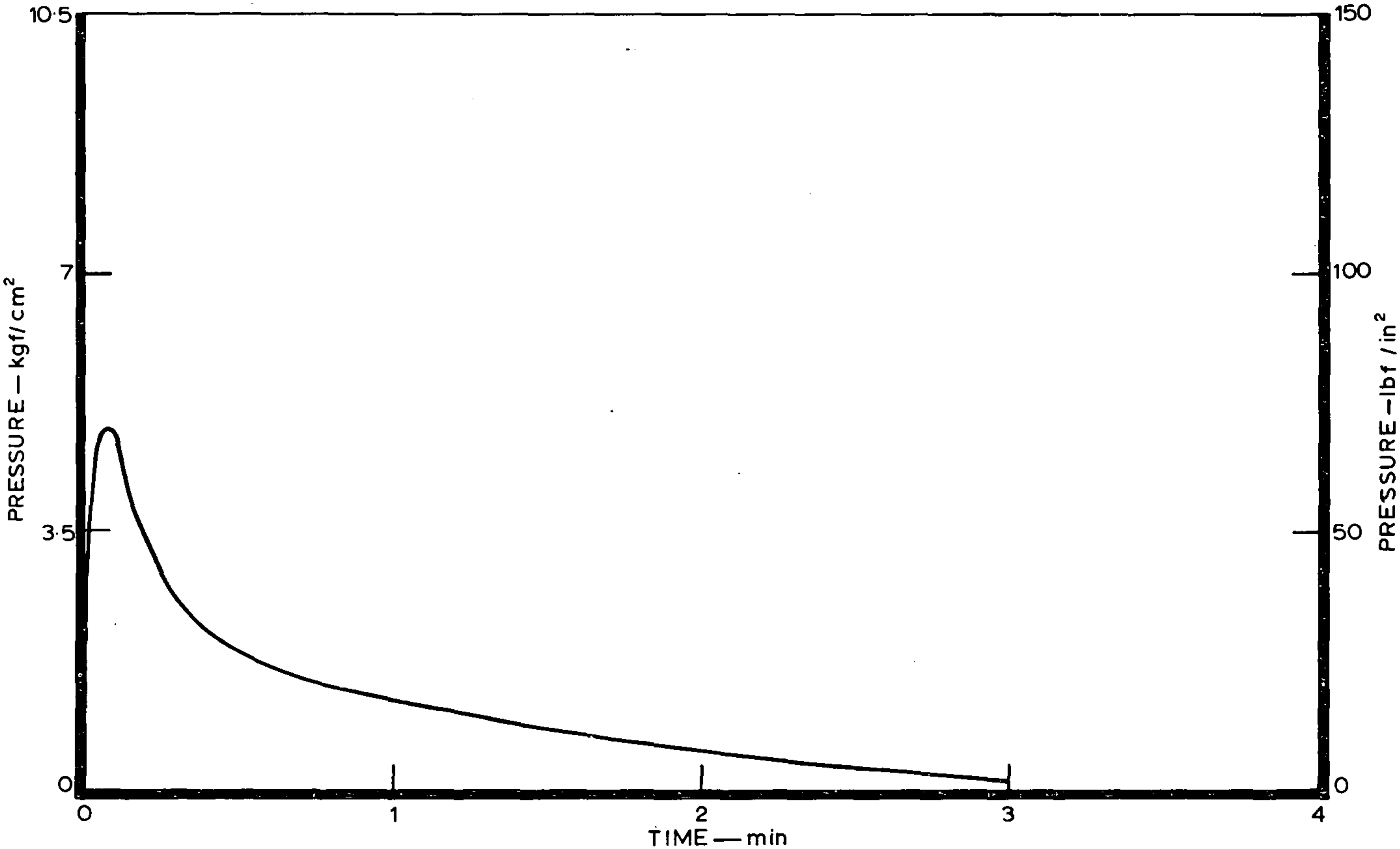

FIG. 2b. TYPE 2 – 9·1-LITRE (2-GALLON) SODA ACID (PLUNGER TYPE) DISCHARGE

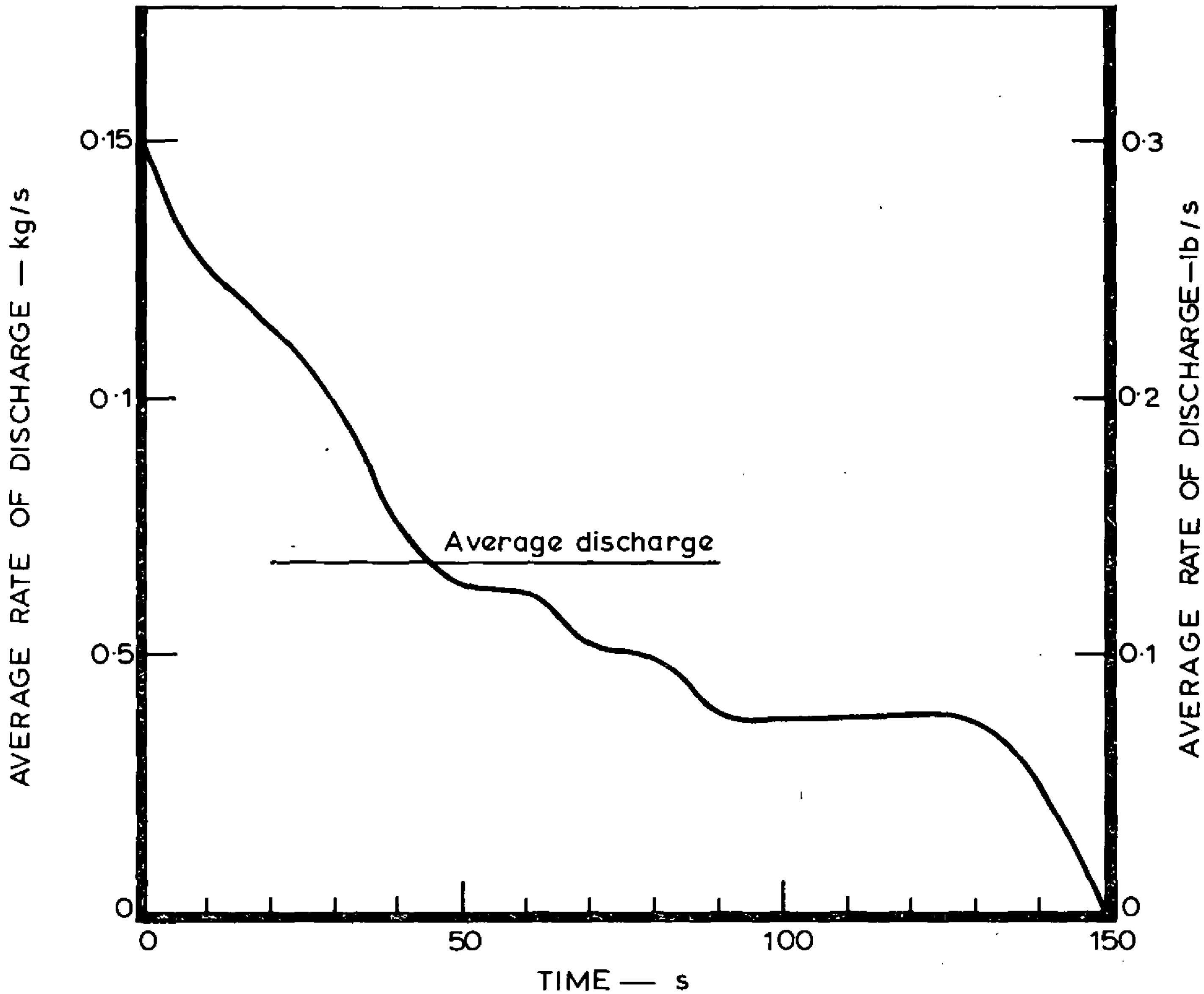

FIG. 2c. TYPE 2—9·1-LITRE (2-GALLON) SODA ACID (PLUNGER TYPE) RATE OF DISCHARGE

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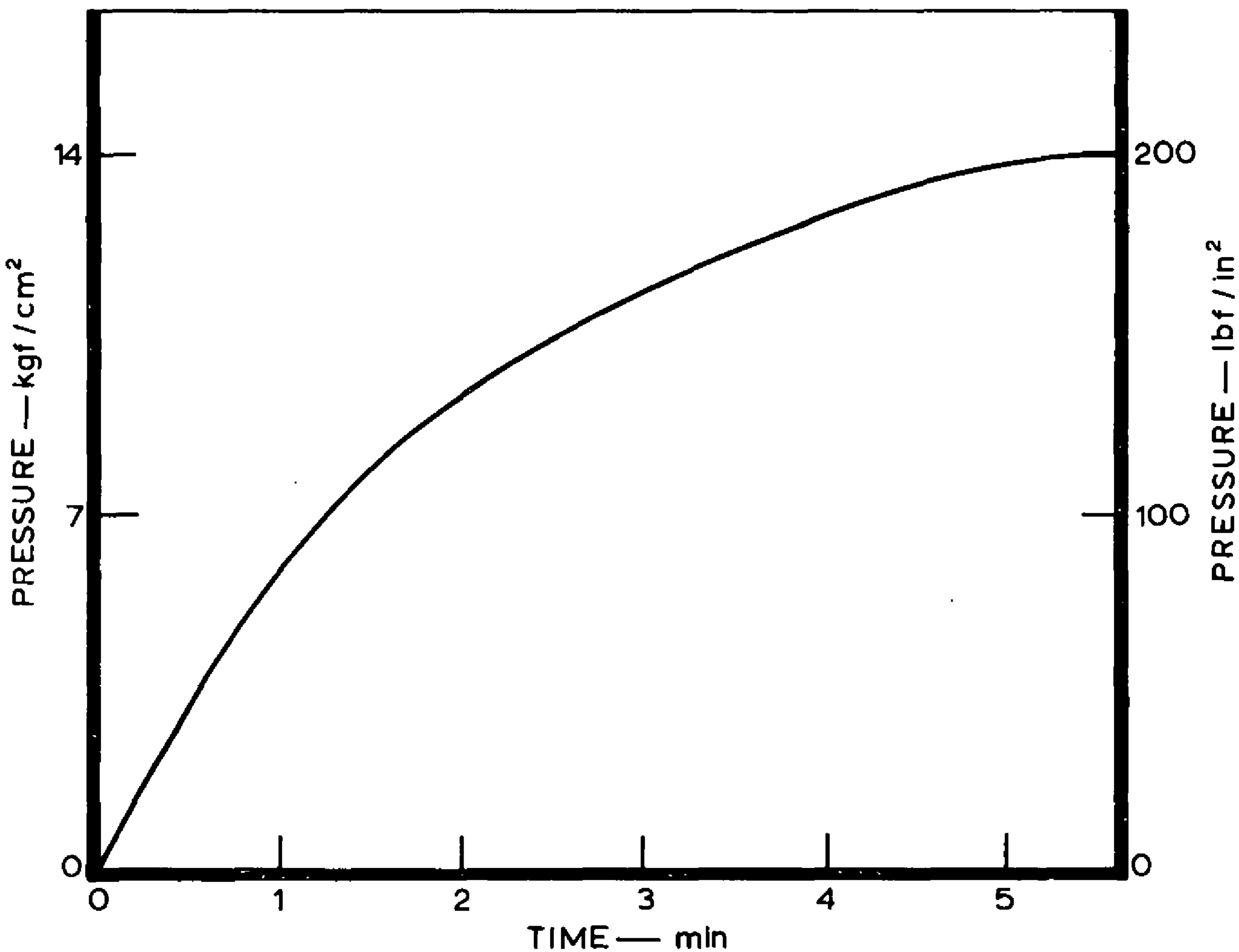

FIG. 3a. TYPE 3–9·1-LITRE (2-GALLON) FOAM, CHEMICAL (TURNOVER TYPE) CLOSED PRESSURE

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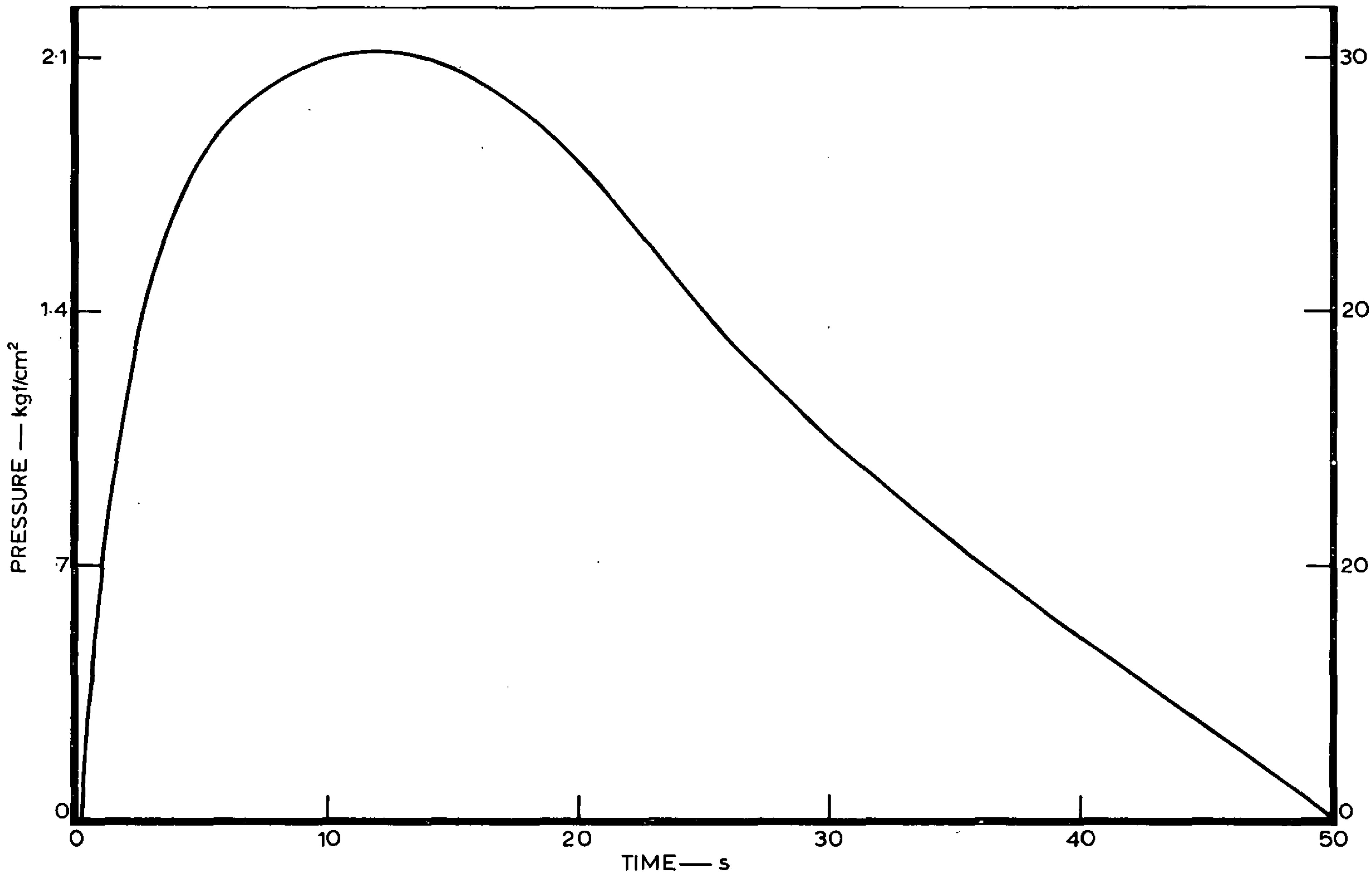

FIG. 3b. TYPE 3—9·1-LITRE (2-GALLON) FOAM, CHEMICAL (TURNOVER TYPE) DISCHARGE

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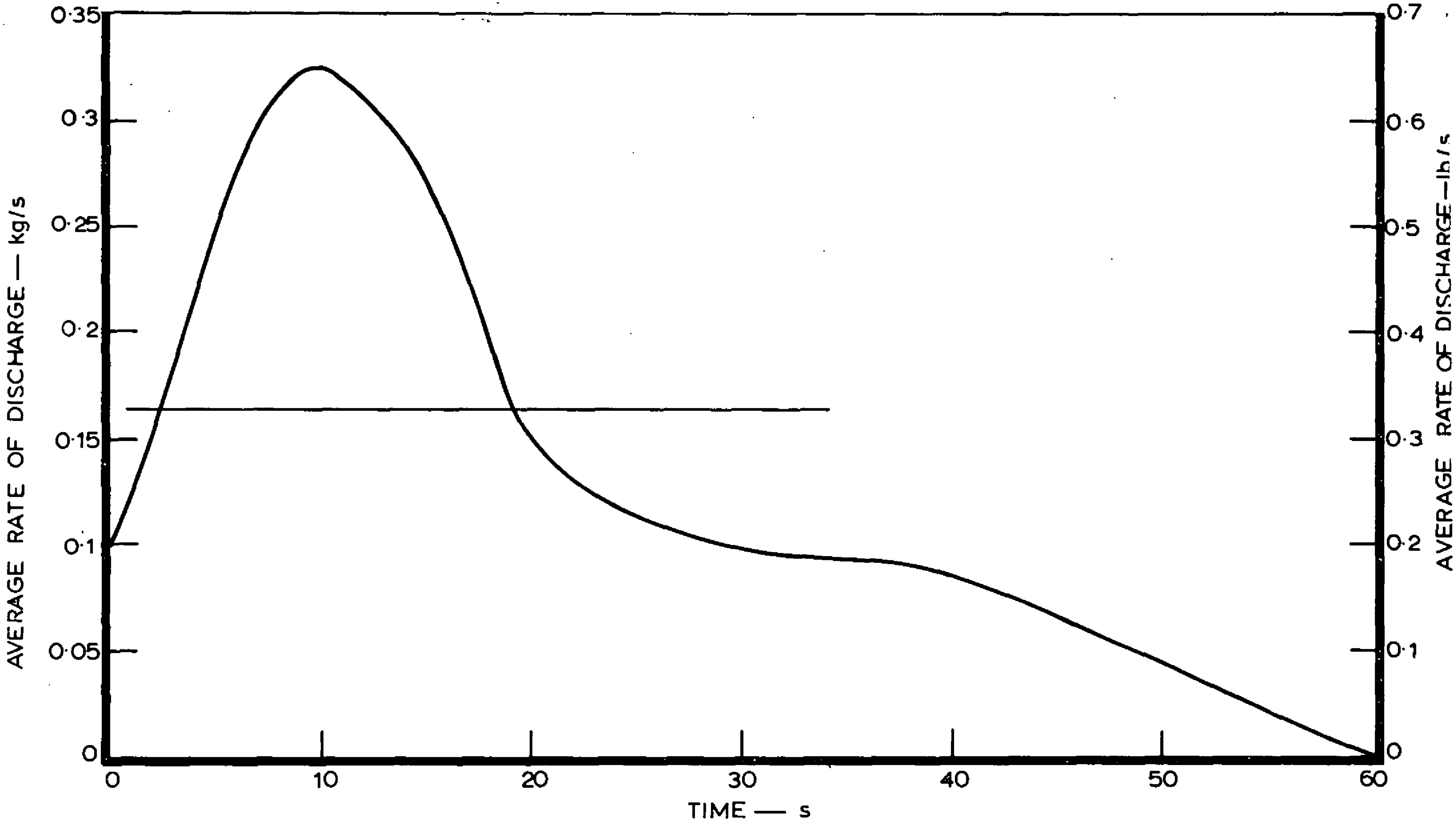

FIG. 3c. TYPE 3—9·1-LITRE (2-GALLON) FOAM CHEMICAL (TURNOVER TYPE) RATE OF DISCHARGE

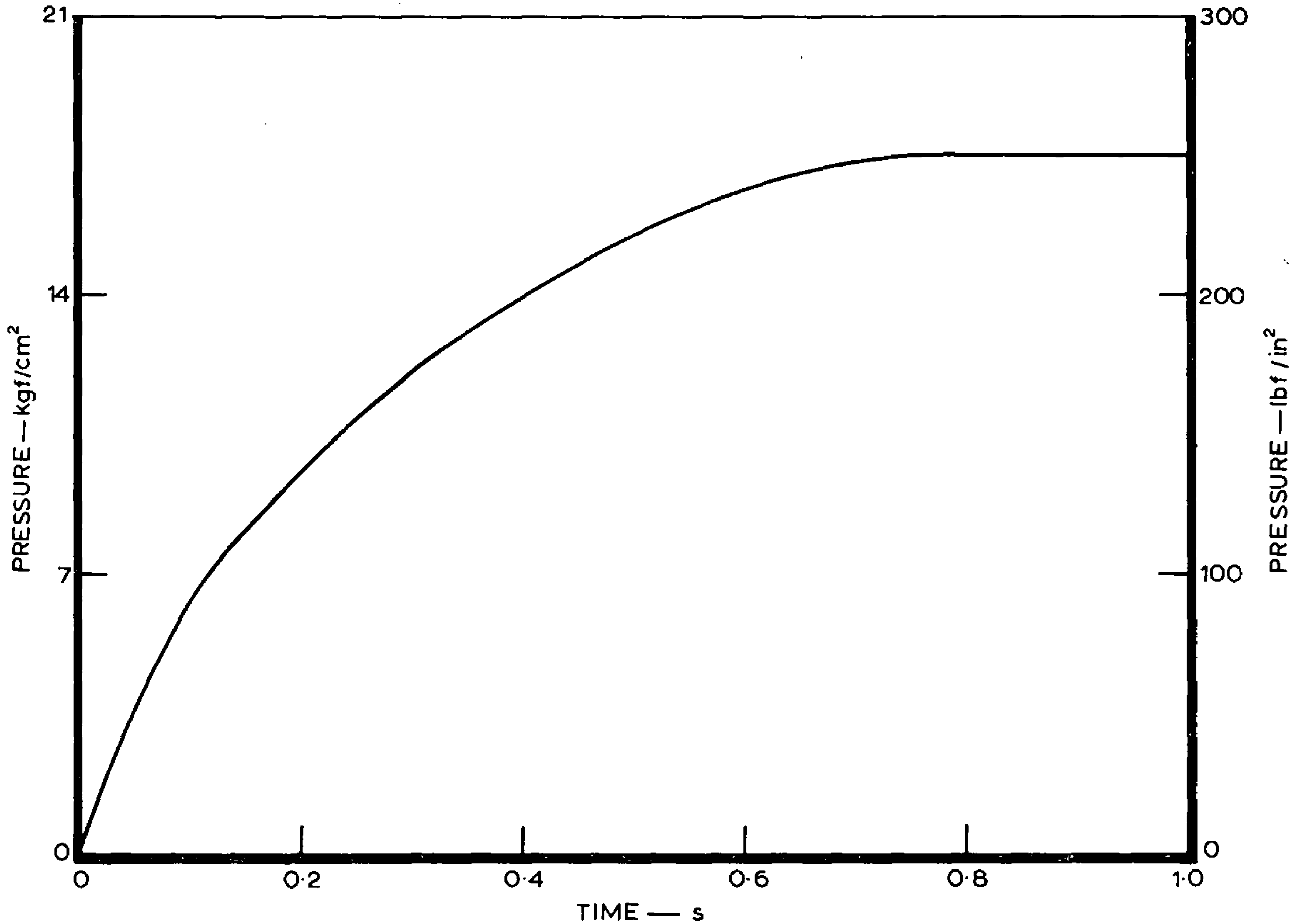

FIG. 4a. TYPE 4—9·1-LITRE (2-GALLON) FOAM (GAS PRESSURE TYPE) CLOSED PRESSURE

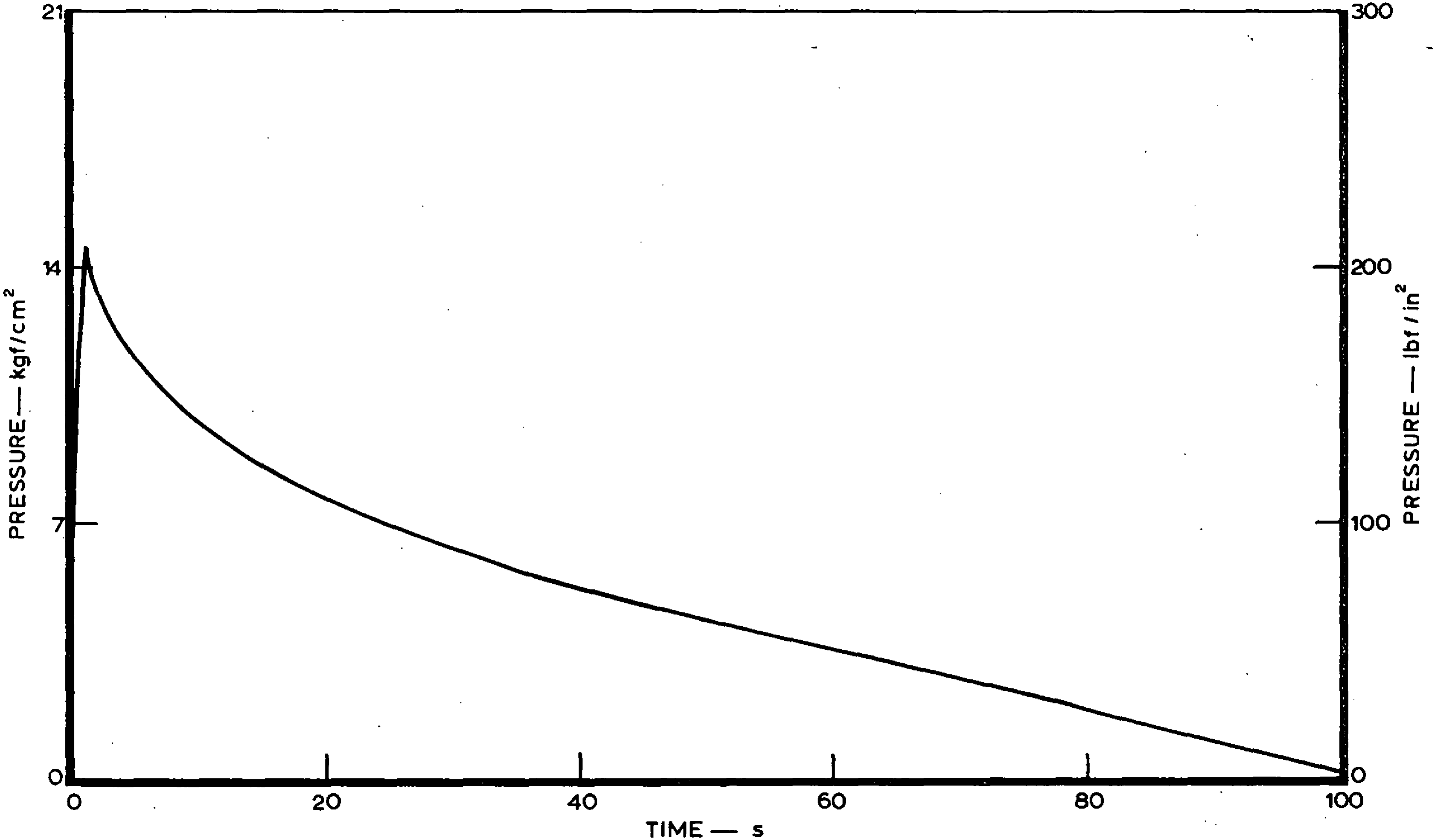

FIG. 4b. TYPE 4 — 9·1-LITRE (2-GALLON) FOAM (GAS PRESSURE TYPE) DISCHARGE

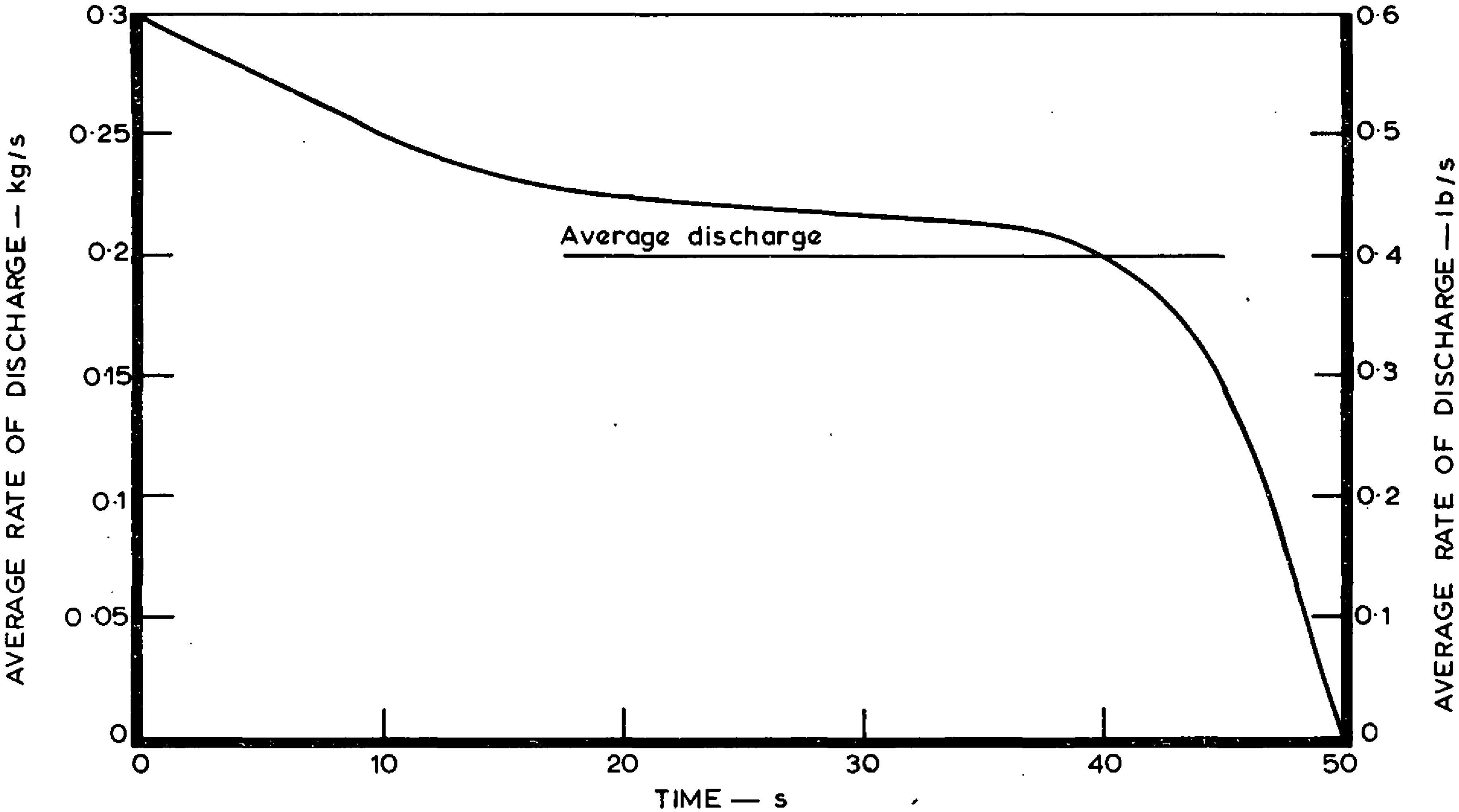

FIG. 4c. TYPE 4 — 9·1-LITRE (2 - GALLON) FOAM (GAS PRESSURE TYPE) RATE OF DISCHARGE

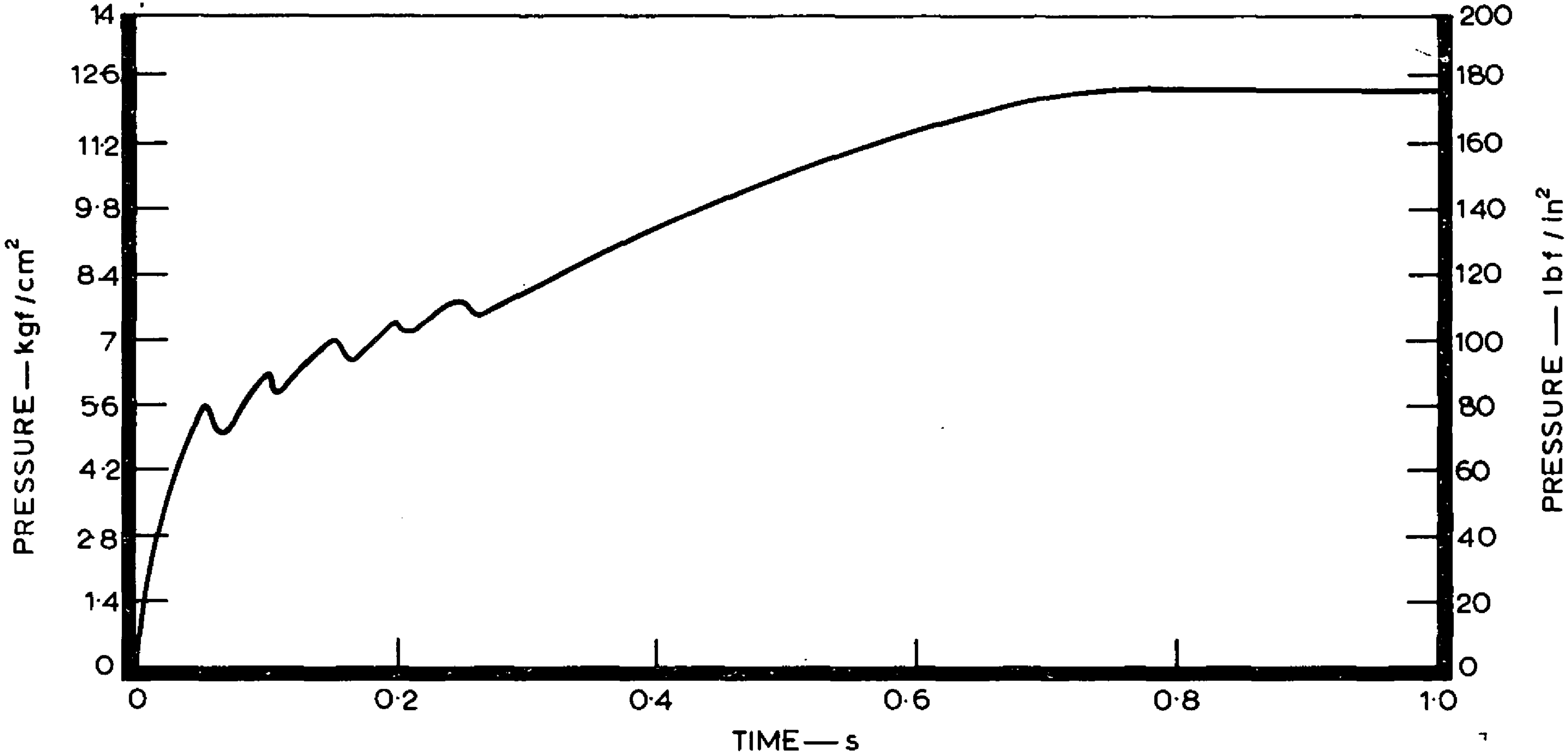

FIG. 5a. TYPE 5 — 9·1-LITRE (2 - GALLON) WATER TYPE (GAS PRESSURE) CLOSED PRESSURE

1/8971 F.R. 767.

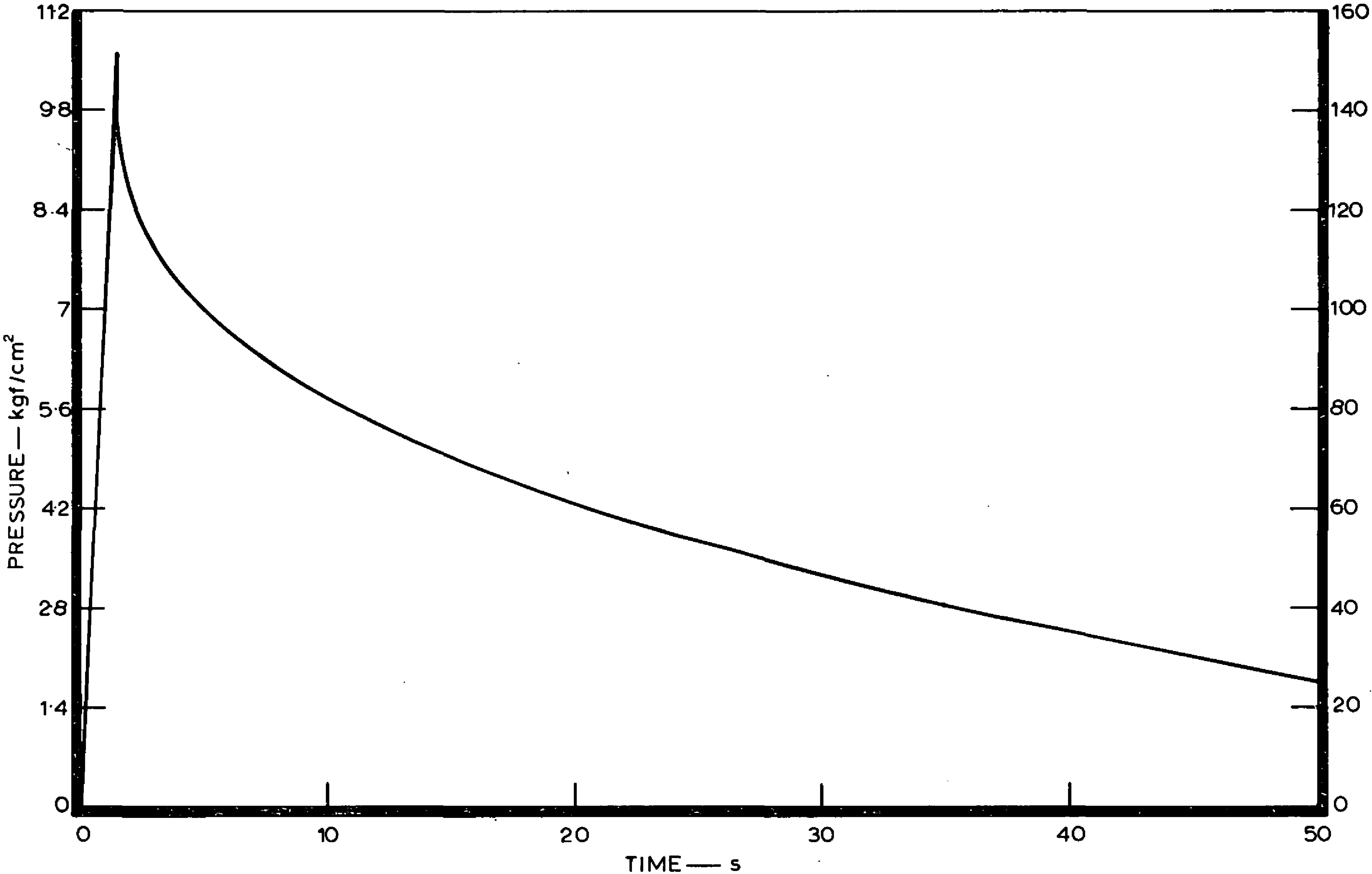

FIG. 5b. TYPE 5—9·1-LITRE (2-GALLON) WATER TYPE (GAS PRESSURE) DISCHARGE

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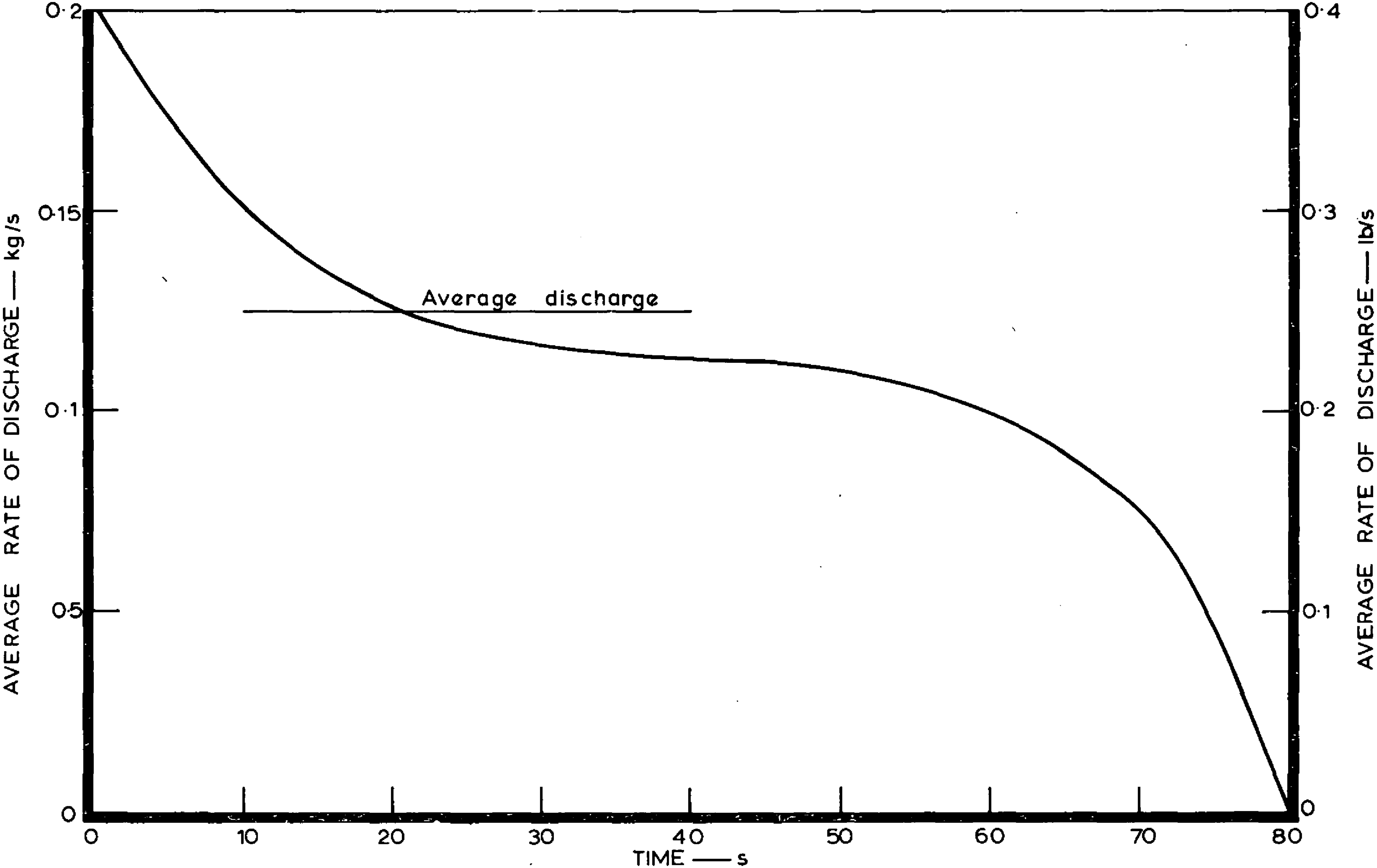

FIG. 5c. TYPE 5—9·1-LITRE (2-GALLON) WATER TYPE (GAS PRESSURE) RATE OF DISCHARGE

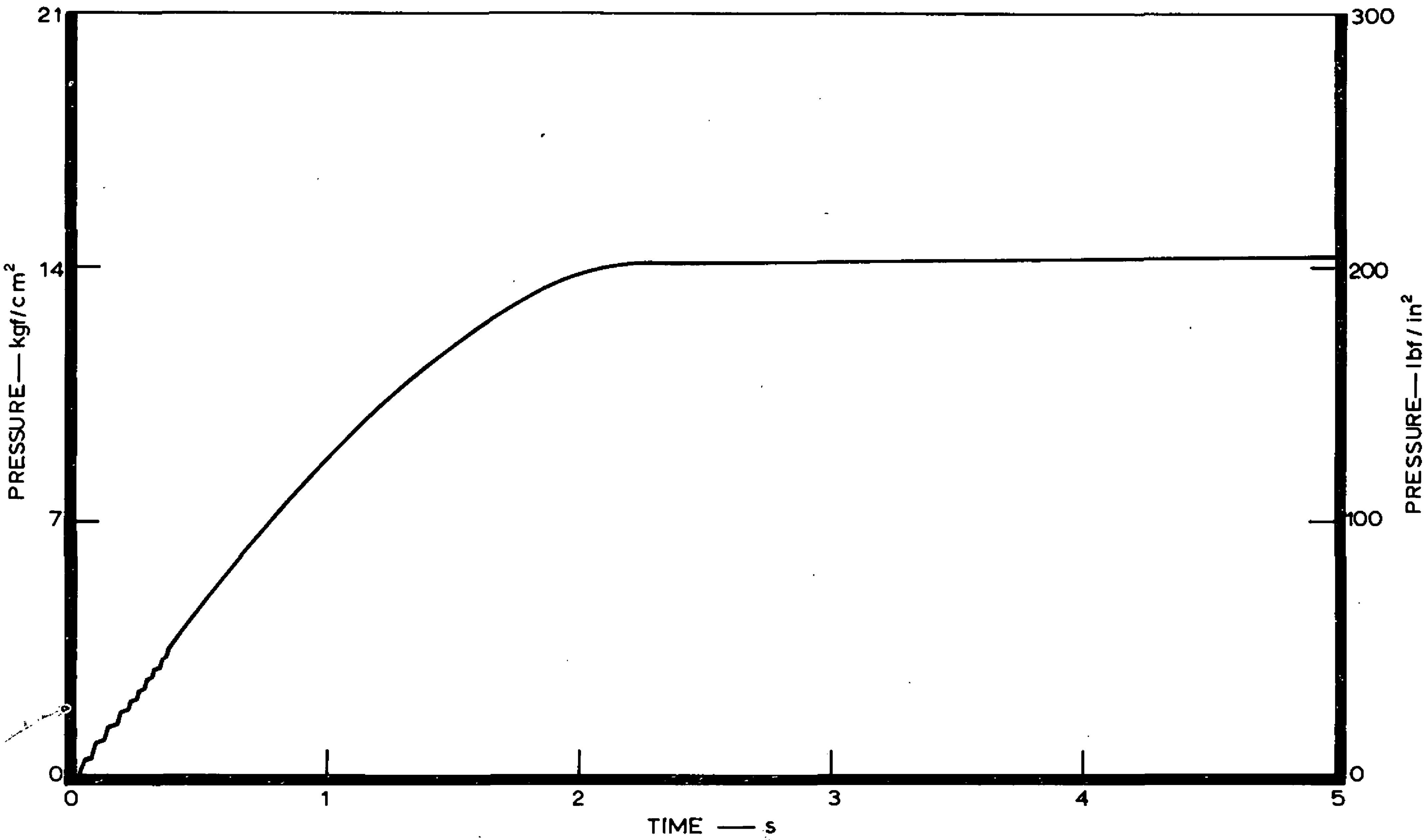

FIG. 6a. TYPE 6 — 9·1-LITRE (2-GALLON) WATER TYPE (GAS PRESSURE, METERED CHARGE) CLOSED PRESSURE

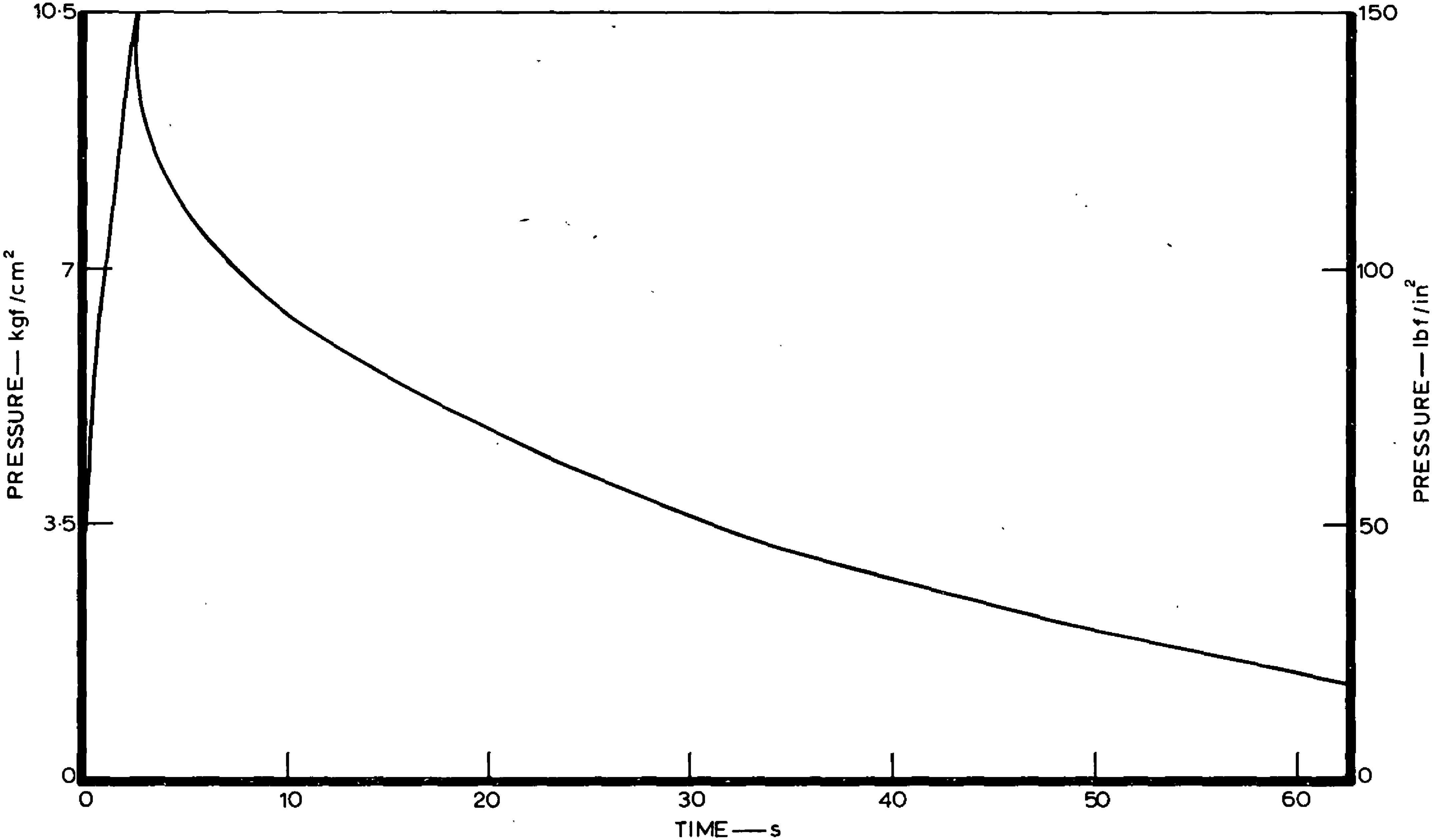

FIG. 6b. TYPE 6 — 9·1-LITRE (2-GALLON) WATER TYPE (GAS PRESSURE METERED CHARGE) DISCHARGE

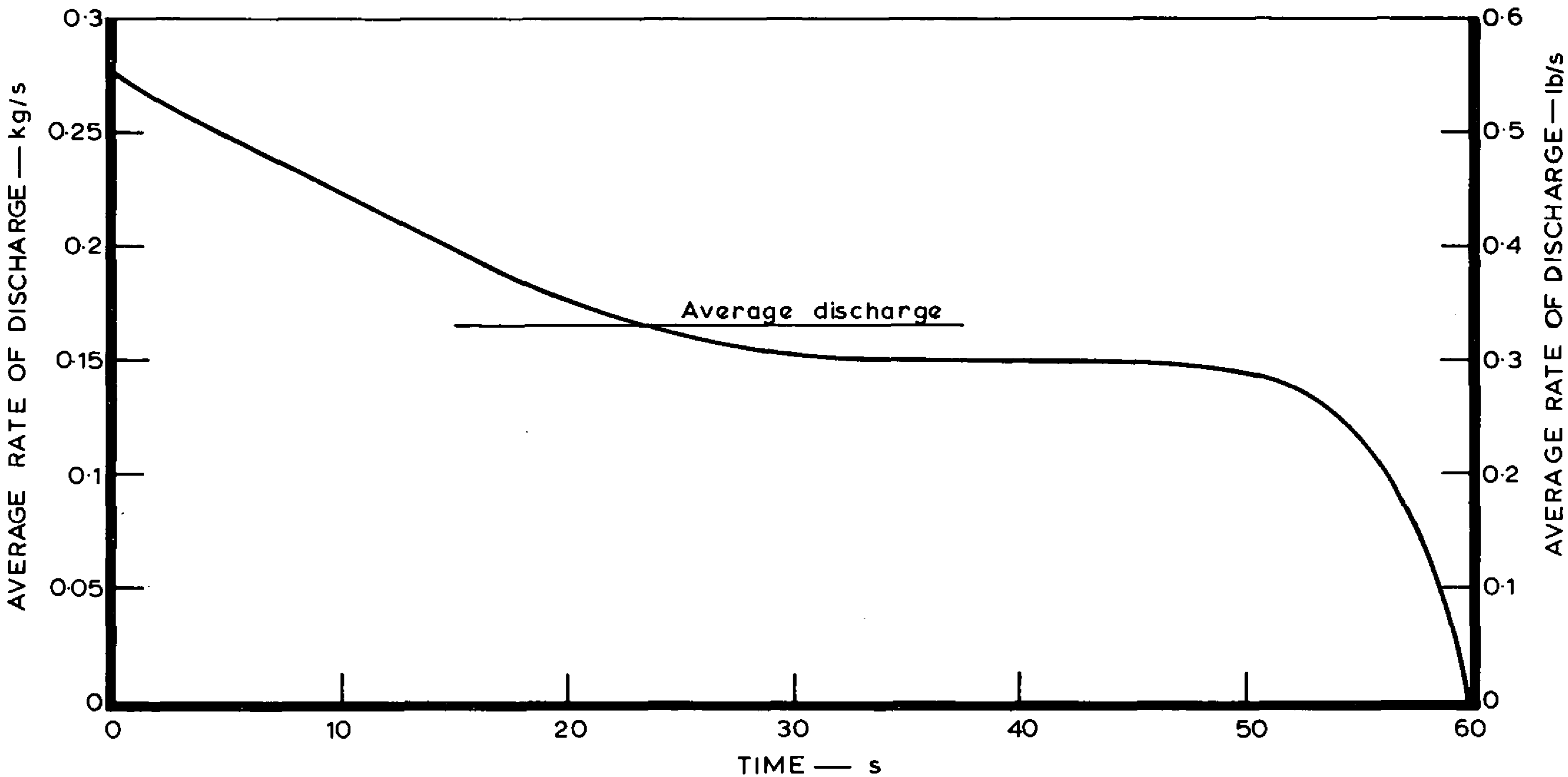

FIG. 6c. TYPE 6—9·1-LITRE (2-GALLON) WATER TYPE (GAS PRESSURE METERED CHARGE) RATE OF DISCHARGE

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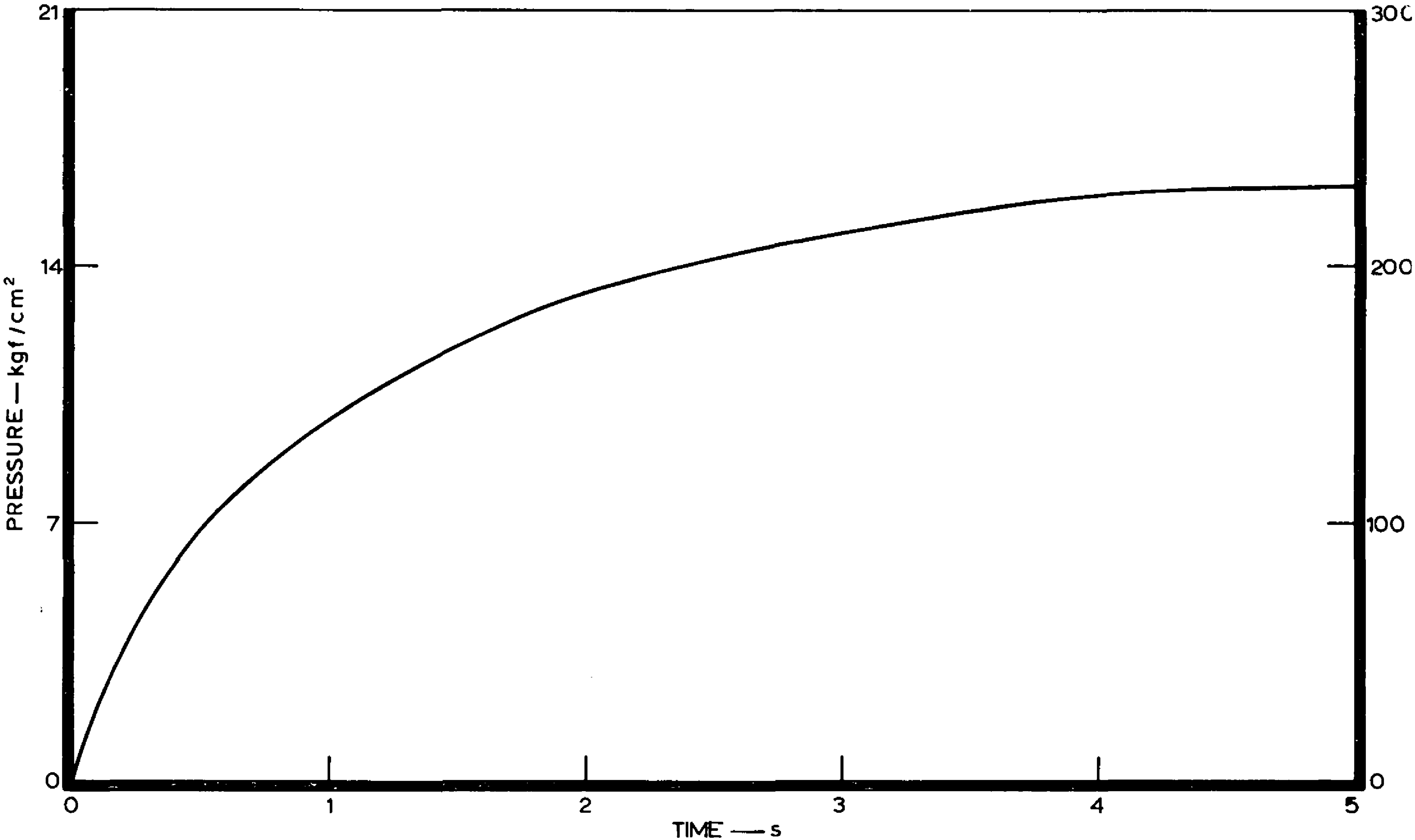

FIG. 7a. TYPE 7— 9·1-kg (20 lb) DRY POWDER (GAS CARTRIDGE TYPE) CLOSED PRESSUR

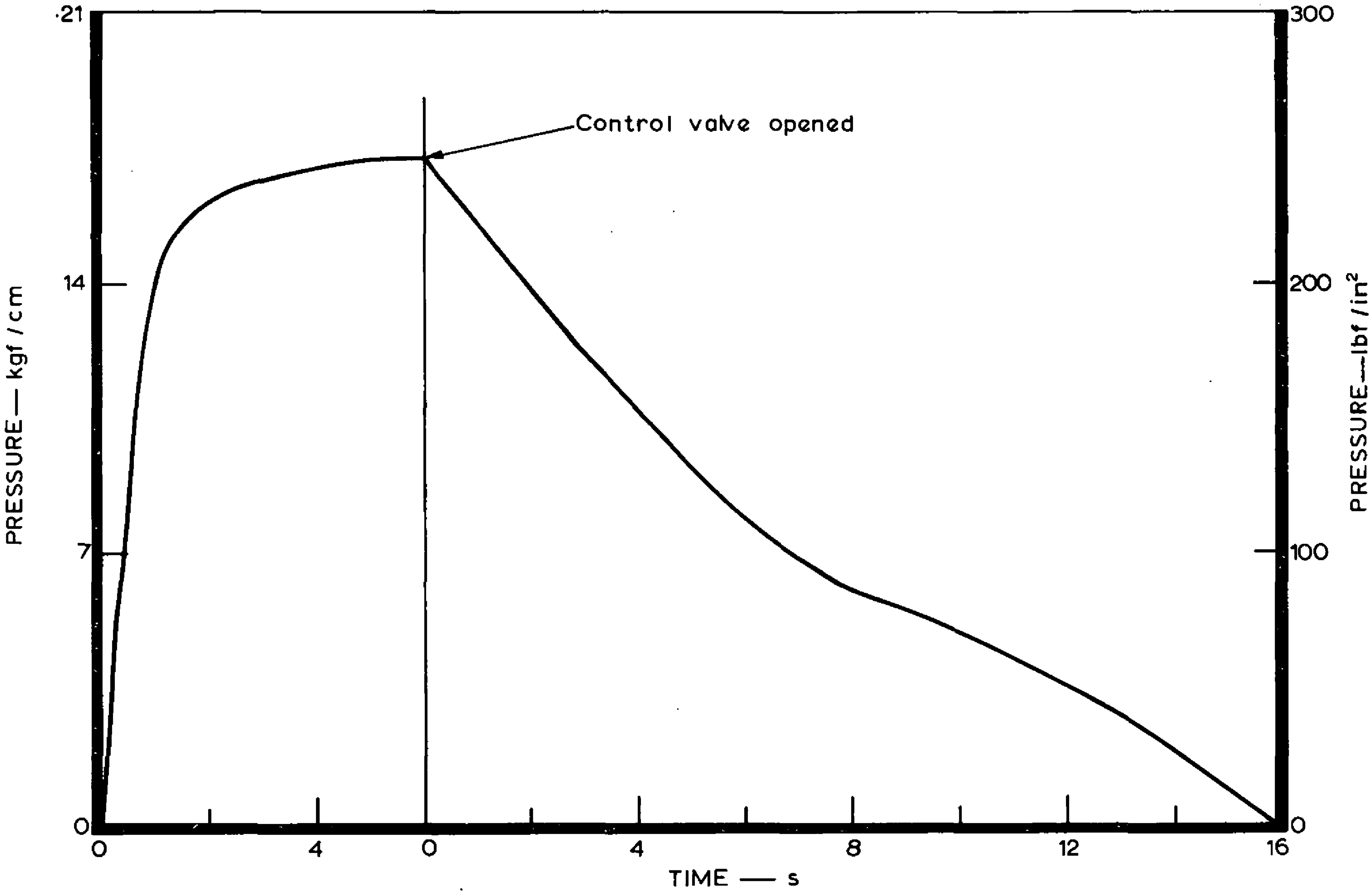

FIG. 7b. TYPE 7—9·1-kg (20 lb) DRY POWDER (GAS CARTRIDGE TYPE) DISCHARGE

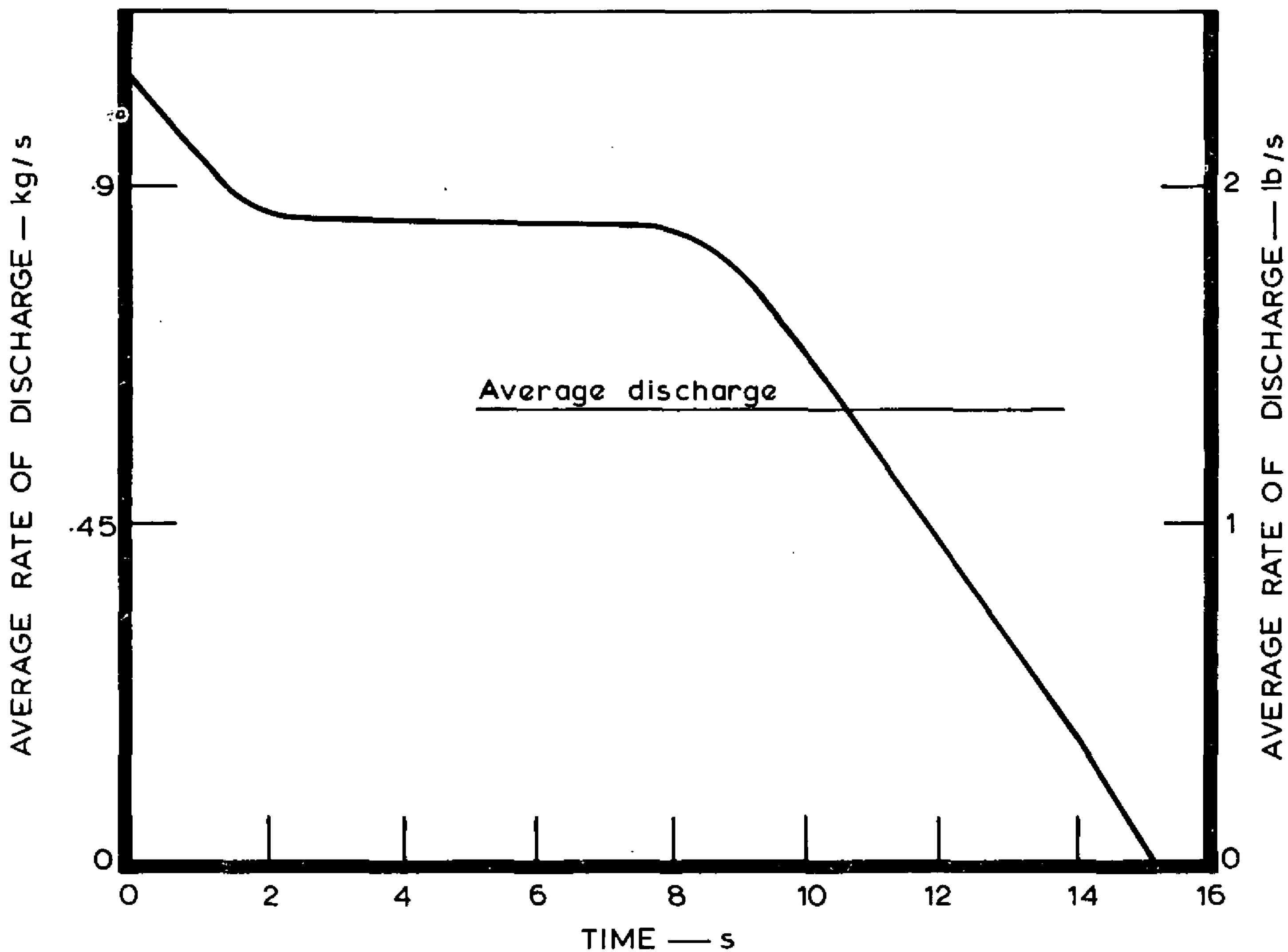

FIG. 7c. TYPE 7— 9·1-kg (20 lb) DRY POWDER (GAS CARTRIDGE TYPE)
RATE OF DISCHARGE