COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/89

UPPER RAMU HYDRO-ELECTRIC PROJECT, PERMEABILITY TESTS IN DIAMOND DRILL HOLES NEW GUINEA, 1963

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RECORDS 1963/89

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UPPER RAMU HYDRO-ELECTRIC PROJECT, NEW GUINEA

PERMEABILITY TESTS IN DIAMOND DRILL HOLES

INTRODUCTION

The following notes have been prepared as a guide to the practical aspects of water pressure testing in diamond drill holes to determine rock permeability. Reference is made to conditions likely to be encountered on the Upper Ramu scheme and a tentative water pressure testing programme is proposed. The procedures are based in part on those described in a Technical Memorandum of the United States Bureau of Reclamation*, and in part on experience gained during investigations by the Bureau of Mineral Resources. Extracts from the U.S.B.R. Memorandum are enclosed by quotation marks.

LENGTH OF TEST SECTION

The length of test section is governed by geological and hydraulic considerations. In strong sparsely jointed rock which stands well in the hole a length of 10 to 20 feet is desirable. The use of test sections longer than 20 feet is inadvisable as permeable zones cannot be located accurately enough and calculations become difficult. However, under exceptionally bad conditions there may be no alternative but to use a test section greater than 20 feet in length. Closely jointed or cleaved rock may tend to cave if a 20-foot section is used, especially in flatly inclined holes; sometimes there is a risk that the packer may be jammed. If caving or jamming during drilling indicates this type of rock, a shorter test section (5 or 10 feet) may result in greater stability of the side of the hole and should be used. In very badly shattered rock or soft unconsolidated ground where casing is necessary, it is usual to drill only about 5 to 10 feet ahead before pressure testing and then driving the casing to the bottom of the hole. In order to test the short freshly exposed section below the casing a special short packer is used immediately below the casing shoe bit. It is useless to seat a conventional packer inside the bottom of casing in such circumstances (see below). Some formations penetrated by the drill hole may be of particular interest to the engineering geologist, and he may wish to have these sections tested in 5-foot lengths for more detailed information.

"At times, due to caving or fissures in the rock, a good seal cannot be obtained for the packer at the planned elevation. Under these circumstances the test section length should be increased or, preferably, decreased, or adjacent test sections overlapped to assure that the test is made with a well-seated packer." Whatever the method chosen, no gaps should be left in the section of hole about which information is required. The engineering geologist will advise, from examination of the core, the best position for the packer. In very broken ground where it is doubtful whether a good seal can be obtained with a single standard packer, two or more packers in series, or an extra long packer, may solve the problem. A method of testing the effectiveness of sealing would be valuable.

"On some tests a 10 or 20-foot section will take more water than the pump can deliver, and no back pressure can be developed. When this occurs, the length of test section should be shortened (to 5 feet say), until the required back pressure can be developed; sufficient tests using the shorter test length should then be made to cover the length of the hole." If a 20-foot section has been drilled and this difficulty occurs, it will be necessary to use two packers to isolate each 5-foot length.

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* Ahrens T.P. "Comments regarding equipment and methods of conducting permeability tests in drill holes." U.S.B.R. Memorandum, January 1951.

"Under no circumstances should a packer be set inside the casing when making a test. The annular space between casing and wall of hole, even when the fit is relatively tight, nearly always offers an easy path of escape for water from the test section. This results in a permeability determination greater than is actually present in the rock."

In the diamond drilling specifications for the Upper Ramu project, (Appendix II, B.M.R. Record No. 1962/95), water pressure test section lengths nominated are 10 or 20 feet for different holes. These should be considered as maximum figures, and the lengths used should be based on the criteria given in these notes. 20-foot sections should only be employed in sound, uniform rock of low permeability, say less than 0.3 g.p.m. per foot of section. In most other conditions 10-foot sections are preferable and greatly facilitate permeability computations.

METHODS OF TESTING

"Drilling 10 or 20 feet of hole and then pressure testing is the most common practice in the Bureau of Reclamation. In rock that tends to cave into the hole and which must be cemented to permit continuation of drilling, it is the only practical method. Where the rock is firm and does not require cementing, the hole may be drilled to the total depth without testing. Two packers are mounted near the end of the rod or pipe used for making the test. The bottom of the rod is sealed and the section between the packers is perforated. The perforations should be at least one-fourth inch in diameter, and the total area of all perforations should be greater than twice the inside cross-sectional area of the rod. Tests are made beginning at the bottom of the hole. When a large drilling programme is under way, this method offers the advantage that the drilling rig may be moved and drilling on another hole started while the pressure testing is done using a tripod and winch at the completed hole." It has, however, one serious disadvantage which is discussed in the next section.

CLEANING OF TEST SECTIONS BEFORE TESTING

Before each test, the test section should be surged vigorously with clear water for ten minutes and then bailed out to remove drill cuttings and rock flour lodged in crevices in the wall of the hole. The surging and bailing can be done with a suitable bailing device on a wire line and should be continued until no sludge is recovered by the bailer. A less satisfactory method of flushing out the hole before testing is to increase the circulation rate suddenly with the hope that most of the residual cuttings will be removed by the increase in water speed. Increased circulation should be maintained for at least five minutes after the returning water has cleared. This method should not be used in fault, or similar, zones where clay is present. Both these methods are practicable for a test section below the water table, but if the section is above the water-table and will not hold water, water should be poured into the hole during surging, then bailed out as rapidly as possible. When a completed hole is to be tested using the two packer method, the entire hole can be surged and bailed in one continuous operation.

"An alternative method to surging and bailing for cleaning a drill hole in consolidated formations prior to pressure testing is the use of a stiff bristled nylon brush on the end of the drill rods. Rotation of the rods, accompanied by circulation of water and a surging action, is an excellent method of cleaning the hole."

During drilling of each section, rod grease or "dope" must not be used within 10 feet of the top of the proposed test section. Such lubricants, when mixed with rock flour, will completely plug many of the finer fissures and often cannot be removed by surging before testing. For this reason pressure testing of a completed hole where rod grease has been used, using two packers may give erroneous results and the stage method is preferable.

Cleaning the hole is frequently omitted from testing procedures, resulting in permeable rock appearing to be tight, whereas it should always be included and systematically carried out.

SIZE OF ROD OR PIPE USED IN TESTS

"Drill rods are used to make pressure tests on many projects. N-size rods can be used for this purpose without seriously affecting the reliability of the data, provided the water loss of the test section does not exceed about $12\frac{1}{2}$ g.p.m.* and the depth to the top of the test section does not exceed about 50 feet." At flow rates and depths greater than these, pressure losses in the rods increase rapidly, pressure loss calculations by graphs or formulae become unreliable, and the resulting permeability figures may be erroneous. The equivalent flow limit for B-size rod is $4\frac{1}{2}$ g.p.m., and for $1\frac{1}{4}$" iron pipe is 19 g.p.m., an increase of 52% over N-size rod for the same friction loss.

For general use, casing or wrought iron or steel pipe are preferred to N or B-size rods for pressure testing because they do not have couplings of restricted internal diameter causing high friction losses as have drill rods. This advantage becomes very marked when deep holes, such as those along the tunnel line of the Upper Ramu project, are tested. In some cases, friction losses in drill rods may be so great that almost the entire power out-put of the pump is absorbed, this preventing the desired pressures from being exerted on the test section. (Kinetic pressure effects are negligible at average flow rates.) It is much more practical and economical to use low friction loss pipe or casing instead of drill rod rather than a pump of very high capacity to overcome this problem.

Depending on the geological conditions and the capacity of the drilling rig, the deep 400-foot holes on the proposed Ramu tunnel line may be drilled to their full depth with N-size drill rods, or to about 200 feet, say, with N-size drill rods and the remainder with B-size drill rods. In the first case, permeability testing near the bottom of the hole could be carried out with N-size drill rods or $1\frac{1}{4}$" iron pipe; in the second case both N and B-size drill rods would be used or $1\frac{1}{4}$" iron pipe. Table 1 gives approximate friction losses at different flow rates for the three methods. The figures are derived from the graphs shown in Plates 5, 6 and 7, which are based on the U.S.B.R. curves reproduced in Plates 1 to 3. The latter are pressure loss curves for $1\frac{1}{4}$" iron pipe and N and B - size drill rods with ordinary couplings. Standard pipe formulae and coefficients can be used, with the usual limitations, to calculate losses in other sizes of casing and pipe.

Table 1

Friction losses in supply line for permeability tests at 400-foot depth

Size of supply line.	Total friction loss, in p.s.i.									
	2	4	6	8	10	12	14	16	18	20
400' $1\frac{1}{4}$" iron pipe	1	3	4	6	8	9	11	13	16	18
400' N-size rod	1	3	4	8	12	16	20	26	33	40
200' N, 200' B rod	3	7	15	27	42	60	84	112	156	200

Flow rate in Imp. galls.per minute.

* Imperial gallons per minute.

The figures show that effective testing of deep holes on the Ramu project cannot be achieved if a large portion of supply line in the hole consists of B-size drill rods, and that only partly effective testing can be achieved if flow rates exceed about 12 g.p.m. when N-size drill rods are used. Table 2 gives the dimensions of low friction loss casing and pipe, which can be substituted for drill rod in NX or BX holes, 2.98" and 2.36" diameter respectively, and which should be used for permeability tests, in either of the circumstances described above.

Table 2

Dimensions of pipe and casing for permeability testing in NX or BX drill holes.

Nominal size of pipe or casing		Inside Diameter (inches)	Outside Diameter (inches)
1¼" standard wrought iron or steel pipe		1.380	1.660
1¼" pipe coupling		-	1.950
1½" standard wrought iron or steel pipe	NX holes only.	1.610	1.900
1½" pipe coupling	NX holes only.	-	2.218
EX flush-jointed casing		1.500	1.812
EX flush-coupled casing		1.625	1.812
EX casing coupling		1.500	1.812
AX flush-jointed casing	NX holes only.	1.906	2.250
AX flush-coupled casing	NX holes only.	2.000	2.250
AX casing coupling	NX holes only.	1.906	2.250

Pressure losses due to restriction of flow and turbulence at couplings will not only cause difficulties during water pressure testing of deep holes but also during drilling. High pressure losses result in heavy drill pump loads, low circulation rates, failure to remove cuttings and consequent damage to drill bits. A partial remedy for the drilling problem at least is to ream out the end of each coupling so that the reduction in bore from drill rod to coupling takes place gradually, thus reducing the turbulence and pressure loss. The strength of the coupling is not affected and tests* have shown that the power required to pump water through rods with modified couplings is reduced by up to 50%.

In conclusion, the main effects of high pressure losses in drill rod detrimental to drilling and to the execution of reliable permeability tests, are as follows:-

a) in some cases it may be impossible to achieve the high effective pressures required for permeability tests in deep holes, and to deliver the necessary volumes of water;

b) it is difficult to calculate the gauge pressures required for a planned series of test section pressures;

c) the significance of any differences in permeability is uncertain. In bad cases, even the order of permeability determined may be open to doubt;

d) heavy pump loads during drilling may seriously affect drilling progress and costs.

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* See Cumming J.D., "Diamond Drill Handbook", p.226. J.K. Smit & Sons, Toronto, Canada.

PUMPING EQUIPMENT

Plate 8 of Record 1962/95, "Detailed Geological Investigation of the Upper Ramu Hydro-electric Project, New Guinea, 1961." shows that the collars of proposed drill holes D.D.4 to D.D.9 are at a considerable elevation above the Ramu River, (approximately 995 feet for D.D.6). Drill circulation water will presumably be kept in drums, tank, or sump at the drill site, but the supply of adequate quantities of silt free water for pressure testing may pose problems. D.D.6, 7, 8, 8A, and 9 are situated between 300 to 800 feet horizontally from Recorder Creek (see Plate 8) which, for the period June to September 1961, only flowed for a short time after heavy rain. D.D.7, 8, 8A and 9 are about 900 feet horizontally from Chasm Creek, which, as its name implies, is bordered by very steep slopes and is inaccessible in many places. During the 1961 geological survey it carried clear water most of the time, only drying up once. D.D.5 is near the head of Loop Creek and D.D.4 is at the head of Dyke Creek; the former usually has a small steady flow, but the latter frequently dries up.

Water requirements for pressure testing will vary from low flow rates of 0.1 (or less) gallons per minute per foot of hole, to average rates between 0.1 and 1 g.p.m./lin.ft., and a probable maximum range of about 1 to 5 g.p.m./lin.ft. in very permeable zones at high test pressures. The duration of each test at a given pressure will vary but should not be less than 25 minutes - 10 minutes or longer to reach stabilization, followed by not less than three constant readings of pressure and flow rate at 5-minute intervals. Therefore the probable average water consumption for a 20-foot section would be 50 to 500 gallons and the consumption for a very permeable 20-foot section would be about 2500 gallons for each pressure test.

It is recommended that multiple pressure testing of each section be carried out until ~~at least~~ five consistent water loss figures have been obtained at five successive pressure increments. To determine whether or not the results are consistent, the water loss in gallons per minute for the section should be plotted against gauge pressure. When five or more points lie on or near a straight line or smooth curve, the set of figures will be satisfactory for permeability computations, and after the readings have been checked as the pressure is reduced, testing of the section is complete. If, after more than five tests at different pressures, irregular results are still being obtained, the water supply, metering and pumping equipment, high pressure pipe in hole, and packer should be checked. After the packer has been re-seated at a slightly different elevation, the pressure tests should be repeated.

In order to speed up multiple pressure tests, two 1500 gallon tanks (or sumps), used alternatively for low to medium consumption test sections and in series for high consumption test sections, would be desirable, and the pump filling them should be capable of delivering not less than 500 gallons per hour. This arrangement would enable pressure testing with silt free water to proceed almost continuously once the packer was in position, and, although consisting of only two small easily handled or constructed storage tanks, could if necessary, provide sufficient water for standard duration tests of all 20-foot sections except those with exceedingly high consumption. The storage tanks allow silt particles to settle out and also provide a means of calibrating the flow meter.

As already pointed out, the collars of D.D.4, 5, 6, 7, 8, 8A, and 9 are rather remote from assured continuous supplies of water, the only sources likely to meet requirements being Chasm Creek, Loop Creek, and the Ramu River. Pits dug in swampy ground near D.D.4, 5 and 6 would not yield water at a sufficient rate for multiple pressure tests. If it is decided to obtain water from the Ramu River, the pump or pumps used should be capable of delivering at the drill site about 500 gallons per hour against a head of 900 to 1000 feet. A supply pump of lower capacity would limit the testing rate in holes of medium or high permeability.

With regard to water and storage facilities for permeability tests, the U.S.B.R. has the following general comments to make:- "On all permeability tests the quality of water used is of primary importance. Water should be clear and silt free. A recommended practice is to pump from the source of supply into a settling and storage tank. A 3000 - gallon canvas tank is ideal for this purpose, but if one is not available, a pit can be dug. The end of the suction line from the centrifugal test pump should be supported several inches above the bottom of the tank or pit to avoid pumping the settled silt and clay. Water for testing should never be stored in or pumped from the slush pit."

Under the water supply conditions likely to exist for pressure testing, (i.e. long supply lines and high lifts), it will be preferable, if not essential, to use a separate pump at the drill site to supply the pressure water to the hole. The U.S.B.R. has very definite views on the best type of pump for this job:- "Many permeability tests are made using the circulation pump on the drill for pumping water. Such pumps are generally the multiple cylinder type with a uniform fluctuation in pressure. They have a maximum capacity of about 25 g.p.m. and if not in good condition may have capacities as low as 17 to 18 g.p.m. Many tests are failures because such pumps do not have sufficient capacity to develop back pressure in the length of hole being tested. When this happens, the tests are generally reported, "took capacity of pump, no pressure developed". This result does not permit determination of permeability of the material tested, when, in such materials, good approximations are most desirable. In addition, the fluctuating pressures of multiple cylinder pumps, even when an air chamber is used, are often difficult to read accurately.

It is strongly recommended that all permeability tests be performed with centrifugal pumps of 250 to 350 g.p.m. capacity against a total dynamic head of 140 to 160 feet. Such pumps will furnish sufficient water of adequate uniform pressure for most tests."

In general, experience gained by the Bureau of Mineral Resources supports these remarks, but permeability tests at the Upper Ramu project will require a pump of rather different specifications.

It is recommended that the 350 to 400-foot holes of the Upper Ramu project be tested at effective pressures up to 195 p.s.i.* If the static ground water level is near the collar of any of these holes, it is possible that the existing hydrostatic pressure at a depth of 400 feet may approach this figure, in which case the pump will have to deliver the necessary quantities of water at pressures up to 195 p.s.i. plus friction losses. Friction losses are discussed in the section on "Size of Rod or Pipe Used in Tests", but, as a guide, will be about 40 p.s.i. at 20 g.p.m. in N-size rod. To meet these requirements, the pump employed for testing the holes should have a cpacity of not less than 100 g.p.m. against a static head of 450 to 500 feet. A three or four stage centrifugal pump directly driven by a petrol engine of about 20 H.P. would be suitable. The pump and engine would each weigh about three to four hundredweight. Alternatively, two smaller pumps could be run in parallel to give an equivalent output. However, for water losses greater than about 20 g.p.m. in N-size rod, and especially those approaching 100 g.p.m., or when a significant proportion of the supply

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* See section on Pressures to be Used in Testing.

line consists of B-size rod, it may be impracticable to conduct satisfactory permeability tests at depths of 300 to 400 feet against high hydrostatic ground water pressures using this equipment. Only with iron pipe or flush jointed casing can friction losses be kept within reasonable limits under these conditions.

PACKERS

Experience during permeability tests at dam sites investigated by the Bureau of Mineral Resources and the Department of Works, has shown that while mechanical packers and hydraulic or pneumatic packers are equally efficient in sound sparsely jointed rock, mechanical packers are not as reliable as the hydraulic or pneumatic types in closely jointed rock. Further, mechanical packers are usually only about 6 to 18 inches long, and in fissured rocks of high permeability leakage may occur by water by-passing the packer and re-entering the hole above the sealed portion after travelling along a short low-resistance leakage path. Pneumatic and hydraulic packers can be made in various lengths up to about 5 feet without practical difficulties and with this length the chance of large by-pass or direct losses is considerably reduced. The use of hydraulic or pneumatic packers is recommended by the Bureau of Mineral Resources if reliable results are to be obtained in all rock types. It is useful to have both a short 1-foot packer and a 3 to 5-foot packer available during tests for the reasons given in the section titled "Length of Test Section".

The leather cup type packer is much in favour with Swiss and Italian construction firms and is of simple construction, but the Bureau has had no experience in its use.

SWIVELS FOR USE IN TESTS

"Swivels used on most drill rigs have a narrow constriction which causes a considerable loss of pressure as water passes through the swivel. A swivel with uniform inside diameter is recommended."

PRESSURE GAUGES

"In most tests the pressure gauge is located between the pump and the water meter, or between the water meter and the swivel. Both locations are undesirable because the actual pressure on the test section will always be less by an unknown amount than that shown on the pressure gauge. The ideal location for the pressure gauge is near the top of the pipe or rod; i.e. between the packer and the swivel. The hole for the gauge should be located below the bottom of the swivel at a distance of at least 10 times the diameter of the pipe or rod."

At least three pressure gauges are required for comprehensive testing, as follows:-

0 - 50 p.s.i. with 1 p.s.i. scale divisions

0 - 100 p.s.i. with 2 p.s.i. scale divisions

0 - 500 p.s.i. with 10 p.s.i. scale divisions.

The pressure gauges should be calibrated at least once a month, and immediately after sustaining any knocks during use.

RECOMMENDED TYPES OF WATER METERS

"Water deliveries in pressure tests may range from less than 1 g.p.m. to as much as 400 g.p.m. No one meter is sufficiently accurate at all ranges to be used. Therefore, two meters for each drilling rig are recommended: a 4 inch impeller type meter to measure flows between 50 and 350 g.p.m., and a 1 inch disc-type meter for flows between 1 and 50 g.p.m. When possible, water meters should be tested at least once a month.

Adapters should be available for each meter. They should be at least 10 times as long as the diameter of the rated size of the meter. This length of adapter permits the water flow to become steady and eliminates the turbulence due to a change in pipe diameter. The accuracy of most meters is influenced adversely by turbulent flow."

LENGTH OF TIME FOR TESTS

The length of time for water pressure tests is discussed in the section on Pumping Equipment.

PRESSURES TO BE USED IN TESTING

"Where subsurface conditions for proposed reservoirs or other water impounding or storage facilities are being investigated, the minimum effective pressure* used in the test section should equal the theoretical head that would be effective at the depth of the test below the maximum level of the reservoir. When tests are made in locations where the ground surface is below the maximum pool level, the use of such test pressure is sometimes impractical because of the dangers of blow-outs or heaving. Under these conditions a safe pressure in all rock is 1 pound per foot of depth from the ground surface to the top of the test section."

When multiple pressure testing is employed, the effective pressures used should, where possible, commence at the theoretical head and rise in 5, 10, or 20 p.s.i. increments for five or more tests. When there is danger of heaving at the surface, the top of the range of multiple pressures must not exceed the maximum safe pressure.

For investigation of high pressure tunnel lines, effective pressures developed at test sections near the proposed tunnel should be roughly equal to the expected difference between tunnel pressure and static ground water pressure. Permeabilities determined from the test results will enable the order of potential leakage to be estimated and may indicate whether or not that section of the proposed tunnel is likely to require lining. Additional information which can be derived from the permeability and ground water head figures is the order of water influx rate during driving of the tunnel.

For investigation of low pressure tunnel lines, such as the proposed Upper Ramu tunnel, situated well below the water table where loss of water is not likely to be a problem under normal conditions, the main purpose of water pressure testing will be to give information

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* The term "effective pressure" means the amount by which the water pressure in the drill hole exceeds the hydrostatic pressure of the groundwater in the immediate vicinity of the drill hole.

on the openness of fractures revealed in the drill core, (i.e. the overall strength or weakness of the interlocking rock blocks) and the magnitude of possible water flows into the tunnel during construction. To provide this information, sections in the vicinity of the tunnel axis should be tested at effective pressures equal to the average annual maximum static groundwater pressure at the axis. With deep tunnels, it may be impossible to achieve these pressures because of the limitations of pumping equipment and hoses (see section on Pumping Equipment). However, for the deepest hole on the Ramu scheme tunnel line (D.D.5), the maximum effective pressure likely to be required is about 195 p.s.i. As discussed in the section on pumping equipment, pipe friction losses have to be overcome, so that the maximum gauge pressure required should be about 235 p.s.i., with 400 feet of N-size rod. A centrifugal pump of the type described should be able to deliver the necessary quantities of water at this pressure. In the event of the water table being considerably below the ground surface at the time of testing, the gauge pressures required will be correspondingly less.

The effective multiple pressures recommended for permeability testing at the Upper Ramu project are given in Table 3. The hydrostatic groundwater pressure at any test section is assumed to be equal to 0.434 x depth below water table, which will have to be estimated from standing water levels in drill holes over the period that drilling is in progress. The values given in Table 3 are based on the greatest groundwater head possible; actual test pressures may not need to be as great. As noted above, the standing water levels will probably be near the collars of most of the drill holes.

In order to calculate the gauge pressures required to produce the effective test pressures given in Table 3, the following formula is used:-

$$P_G = P_E - P_R + P_{GW} + P_F$$

where P_G is the gauge pressure required for the test

P_E is the <u>effective</u> pressure required in the test section

P_R is the hydrostatic pressure of water in the drill rod or supply line at the top of the test section

P_{GW} is the hydrostatic pressure of groundwater at the top of the test section

P_F is the pressure loss due to pipe friction.

Values for P_E are obtained from Table 3; P_R from Plate 10; P_{GW} from Plate 11; and P_F from Plates 5 to 9. In some cases it may not be possible to test deep sections at the lower effective pressures specified in Table 3 if the ground water level is only a short distance above the test section. If this occurs all pressures in the range should be increased by the same amount or else the increments made smaller.

TABLE 3

Recommended range of effective test pressures

Hole No.	Inclination (degrees)	R.L. of collar. (feet)	R.L. Full storage (assumed) (feet)	Distance from collar to top of test section (feet)	Approximate vertical distance from ground surface to top of test section (feet)	Recommended range of effective test pressures P_E (p.s.i.)	Increments No. x Amount (p.s.i.)	Maximum safe pressure (p.s.i.)	Notes
D.D.1	-40°	3877	3880	0 to 20	0	5	0	5	Low angle hole beneath river.
				20 to 40	10' max.	10	0	10	
				40 to 60	20' max.	15 to 20	1 x 5	20	
				60 to 80	20	15 to 20	1 x 5	20	
				80 to 100	30	25 to 30	1 x 5	30	
				100 to 120	40	30 to 40	2 x 5	40	
				120 to 140	50	35 to 50	3 x 5	50	
				140 to 160	65	40 to 60	4 x 5	65	
				160 to 180	80	45 to 65	4 x 5	80	
				180 to 200	100	50 to 90	4 x 10	100	
D.D.1A	-80°	3870	3880	0 to 10	0	5	0	5	Shallow hole in northern abutment rock.
				10 to 20	10	10	0	10	
				20 to 30	20	15 to 20	1 x 5	20	
				30 to 40	30	20 to 30	2 x 5	30	
				40 to 50	40	25 to 40	3 x 5	40	
D.D.1B	-60°	3864	3880	0 to 10	0	5	0	5	Shallow hole in southern abutment rock.
				10 to 20	10	10	0	10	
				20 to 30	20	15 to 20	1 x 5	20	
				30 to 40	30	20 to 30	2 x 5	30	
				40 to 50	45	25 to 45	4 x 5	45	
D.D.2	-80°	3920	3880	40 to 50	35	15 to 35	4 x 5	35	Inclined hole at tunnel intake.
				50 to 60	45	20 to 40	4 x 5	45	
				60 to 70	50	25 to 45	4 x 5	50	
				70 to 80	60	30 to 50	4 x 5	60	
D.D.2A	-45°	3920	3880	60 to 70	65	30 to 50	4 x 5	Not significant	Inclined hole at tunnel intake contingent on D.D.2.
				70 to 80	80	35 to 75	4 x 10		
				80 to 90	95	40 to 80	4 x 10		
				90 to 100	105	45 to 85	4 x 10		
D.D.3	-45°	3948	3880	100 to 110	115	50 to 90	4 x 10	Not significant	Inclined hole near tunnel intake.
				110 to 120	125	55 to 95	4 x 10		
				120 to 130	135	60 to 100	4 x 10		
				130 to 140	145	65 to 105	4 x 10		
D.D.4	-80°	4165	-	270 to 290	250	45 to 125	4 x 20	Not significant	Deep hole on tunnel line. Actual effective test pressures used could be less depending on ground water level along tunnel line.
				290 to 310	270	55 to 135	4 x 20		
				310 to 330	290	65 to 145	4 x 20		
				330 to 350	310	75 to 155	4 x 20		
				350 to 370	330	85 to 165	4 x 20		

TABLE 3 SHEET 2

Hole No.	Inclination (degrees)	R.L. of collar. (feet)	R.L. Full storage (assumed) (feet)	Distance from collar to top of test section (feet)	Approximate vertical distance from ground surface to top of test section (feet)	Recommended range of effective test pressures P_E (p.s.i.)	No. x Amount (p.s.i.)	Maximum safe pressure (p.s.i.)	Notes
D.D.5	- 80°	4200	-	300 to 320 320 to 340 340 to 360 360 to 380 380 to 400	300 320 340 360 380	70 to 150 80 to 160 90 to 170 100 to 180 110 to 190	4 x 20 4 x 20 4 x 20 4 x 20 4 x 20	Not significant	Deep hole on tunnel line.
D.D.6	- 80°	4175	-	290 to 310 310 to 330 330 to 350 350 to 370 370 to 390	320 340 360 380 400	75 to 155 85 to 165 95 to 175 105 to 185 115 to 195	4 x 20 4 x 20 4 x 20 4 x 20 4 x 20	Not significant	Deep hole on tunnel line.
D.D.7	- 60°	3900	-	40 to 60 60 to 80 80 to 100	20 35 45	5 to 20 10 to 30 20 to 40	3 x 5 4 x 5 4 x 5	20 35 45	Inclined hole at tunnel outlet.
D.D.8	- 90°	3935	-	60 to 80 80 to 100 100 to 120	60 80 100	5 to 45 15 to 55 25 to 65	4 x 10 4 x 10 4 x 10	60 80 100	Vertical hole near tunnel outlet.
D.D.8A	- 60°	3935	-	70 to 90 90 to 110 110 to 130	50 60 70	15 to 35 5 to 45 10 to 50	4 x 5 4 x 10 4 x 10	50 60 70	Inclined hole at tunnel outlet, contingent on D.D.8.
D.D.16	- 90°	3195	-	0 to 10 10 to 20 20 to 30 30 to 40 40 to 50	0 10 20 30 40	5 5 to 10 5 to 20 10 to 30 20 to 40	0 1 x 5 3 x 5 4 x 5 4 x 5	5 10 20 30 40	Shallow hole at power house site.
D.D.17	- 90°	3195	-	0 to 10 10 to 20 20 to 30 30 to 40 40 to 50	0 10 20 30 40	5 5 to 10 5 to 20 10 to 30 20 to 40	0 1 x 5 3 x 5 4 x 5 4 x 5	5 10 20 30 40	Shallow hole at power house site.

WATER TABLE

"Continuous daily records should be kept of the water level in the hole throughout drilling operations and at weekly or monthly intervals thereafter for as long as geologist, engineer or hydrologist considers necessary. The best time to make the daily reading is immediately prior to starting drilling operations for the day, assuming that only one daylight shift is being worked. There are numerous devices available for recording water levels in drill holes. The depth below collar should be recorded, together with time and date. If no water table is found this should be clearly stated."

RECORDING RESULTS

All data from permeability tests should be recorded in triplicate on a standard form. A suggested layout is given on the specimen "Diamond Drilling - Pressure Testing Report Sheet" attached (Table 4), which is the same as that used by the Snowy Mountains Hydro-electric Authority.

BUREAU OF MINERAL RESOURCES

GEOLOGICAL SECTION

DIAMOND DRILLING - PRESSURE TESTING REPORT 196

HOLE NO. PROJECT FEATURE LOCATION

DATE	SECTION TESTED		TIME OF START OF TEST	TIME OF TEST	GAUGE PRESSURE	WATER METER READINGS		LOSS	LEAKAGE RATE	SEALING PROPERTIES	REMARKS
						START	FINISH				
	FROM	TO	H.M.S.	MIN.	LB/ SQ. IN.	GAL	GAL.	GAL.	GAL./MIN		

DEPTH TO GROUND WATER IN HOLE BEFORE TEST......FT....IN. MEASURED FROM COLLAR-OF-HOLE AT (TIME) .... (DATE).....................

WATER METER Make........................ Type.................... Serial No.................. Calibration Date..........

PUMP Make........................ Type........................ Serial No.................. Tested Capacity.....Gal/Min.

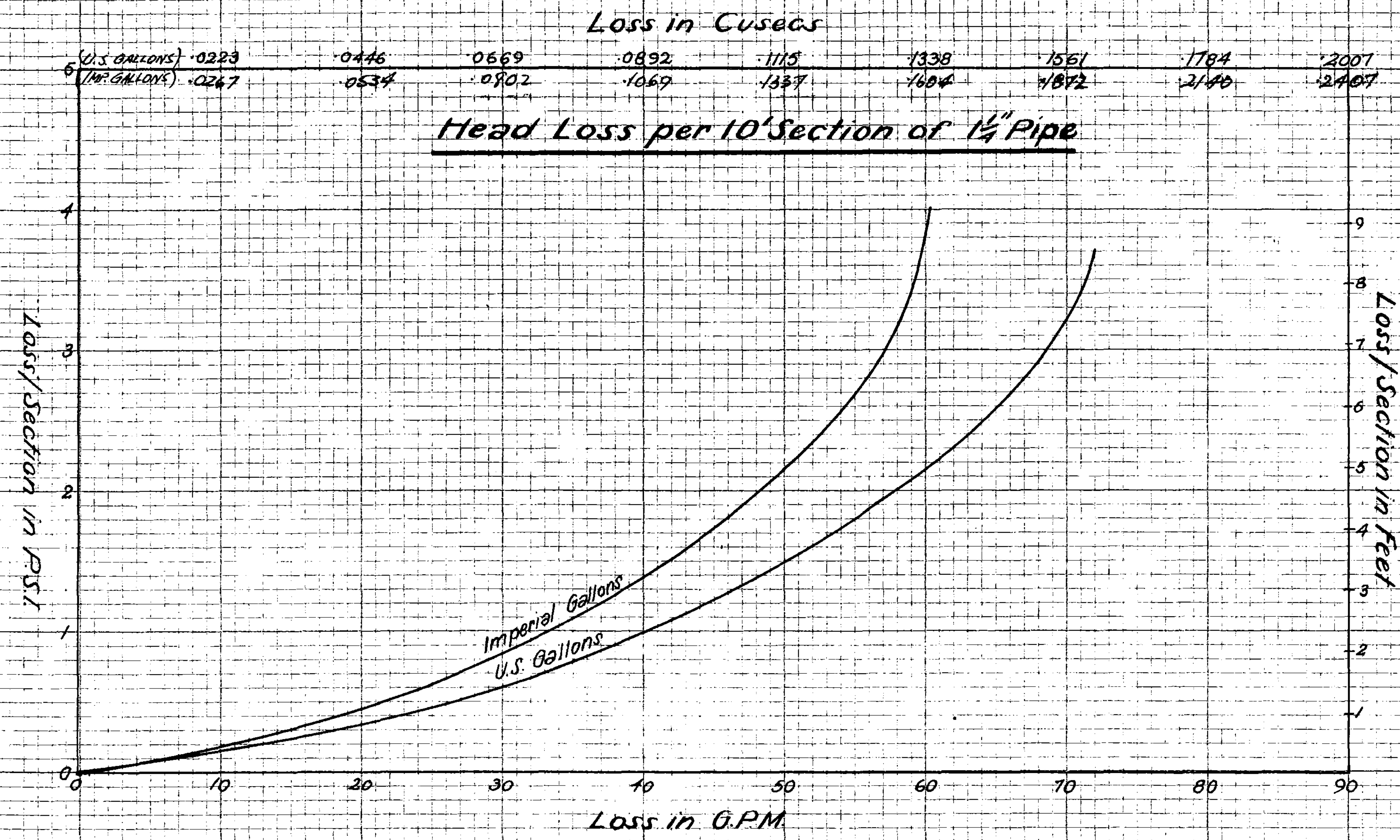
PRESSURE GAUGE Capacity.....LB/SQ/IN., Serial No................. Calibration Date..................

PACKERS Type............. Number..........Total Length.........

RODS OR PIPE Size X Length Below Pressure Gauge..................

Depth of Hole on Drilling .... NMLC.......... BMLC...........
Depth of Hole on Testing......... NMLC.......... BMLC...........
Hole cased to.................feet. Height of Collar............
Angle of Hole...................... Direction of Hole............
TESTER:............................. Date.......................
FOREMAN:............................ Date.......................
DRILLING SUPERINTENDENT..................Date.................
GEOLOGIST:.......................... Date...............
Checked by:......................... Date...............

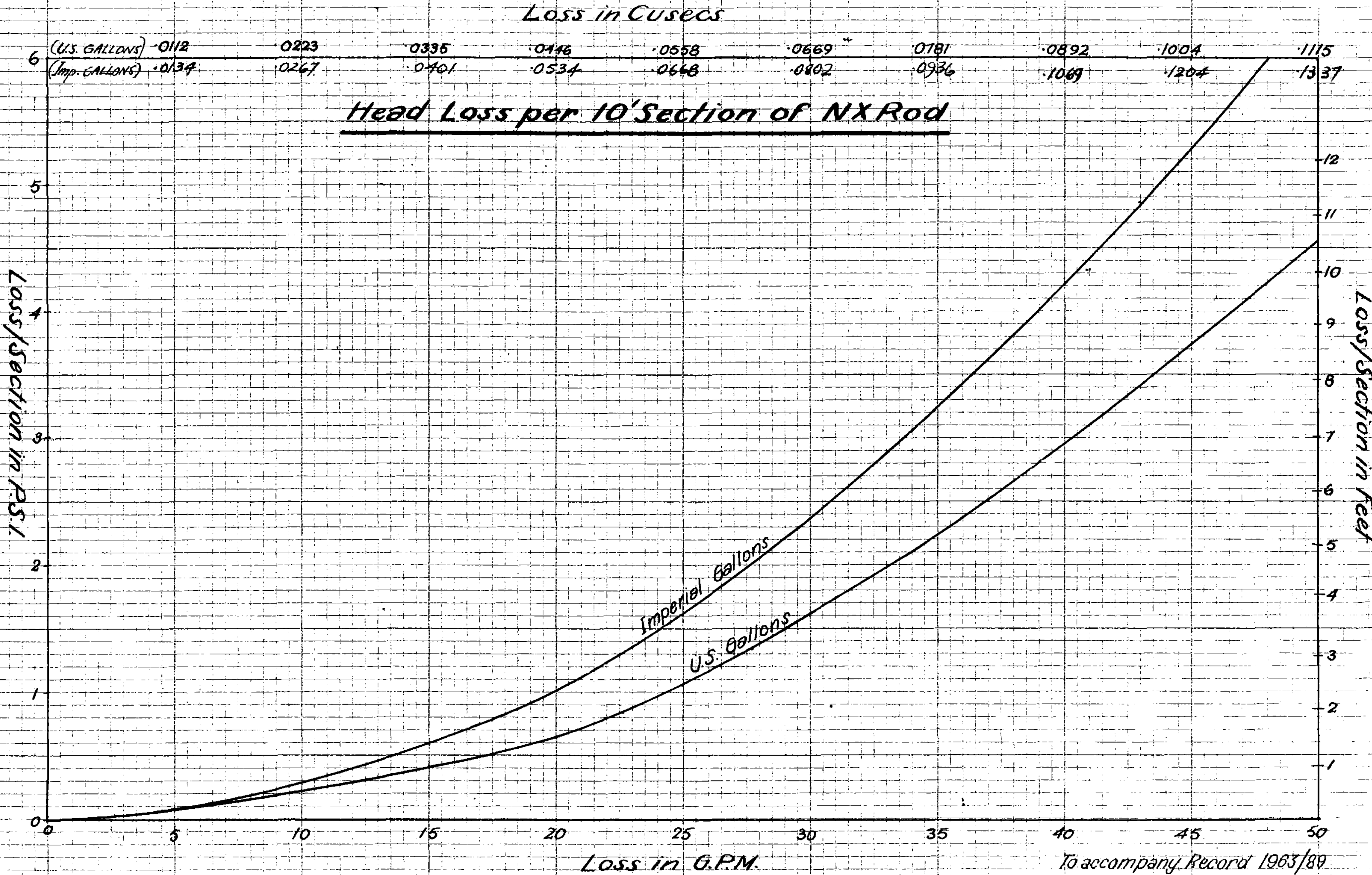
PLATE 1



After U.S.B.R.

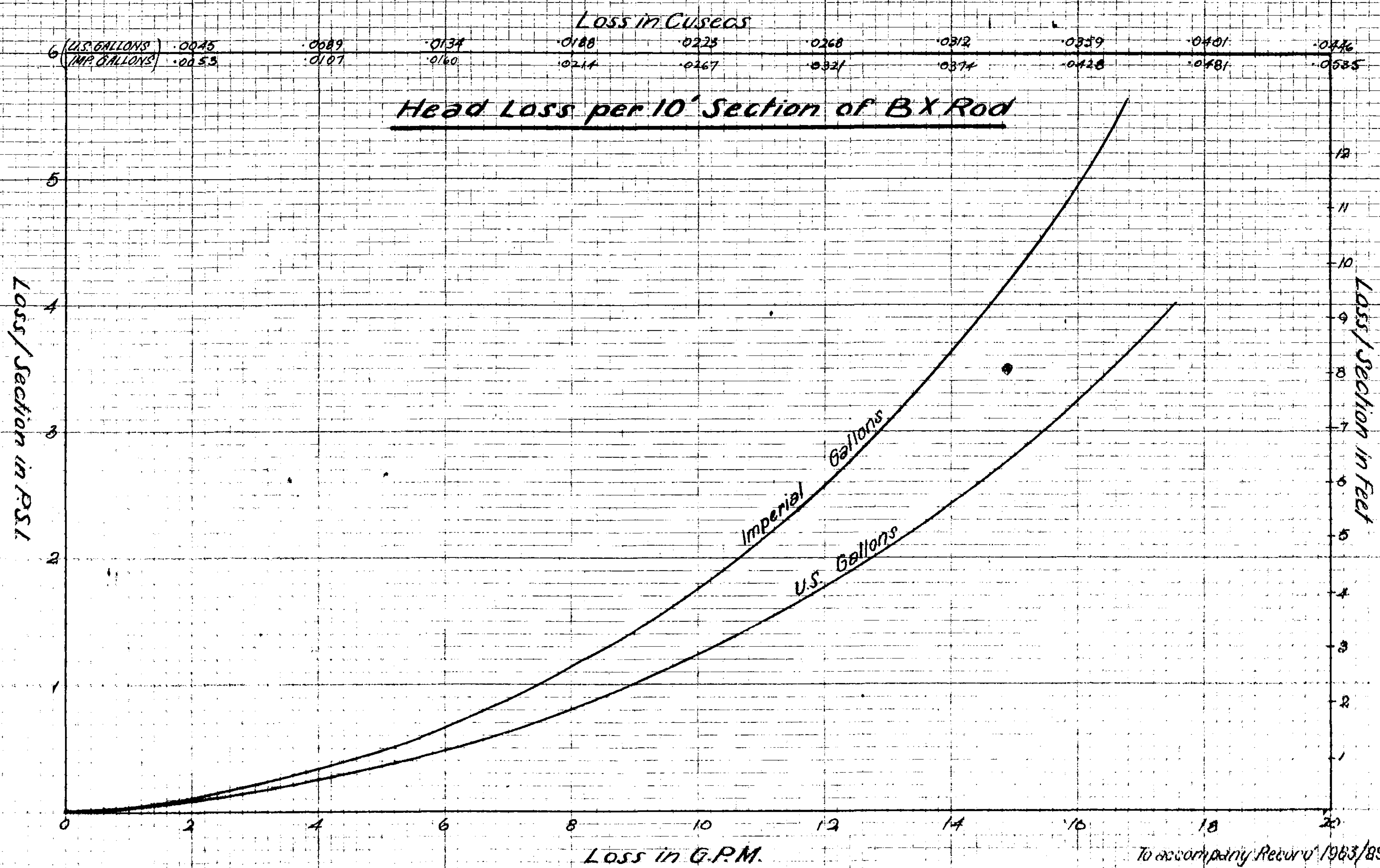
To accompany Record 1963/89

PLATE 2



After U.S.B.R.

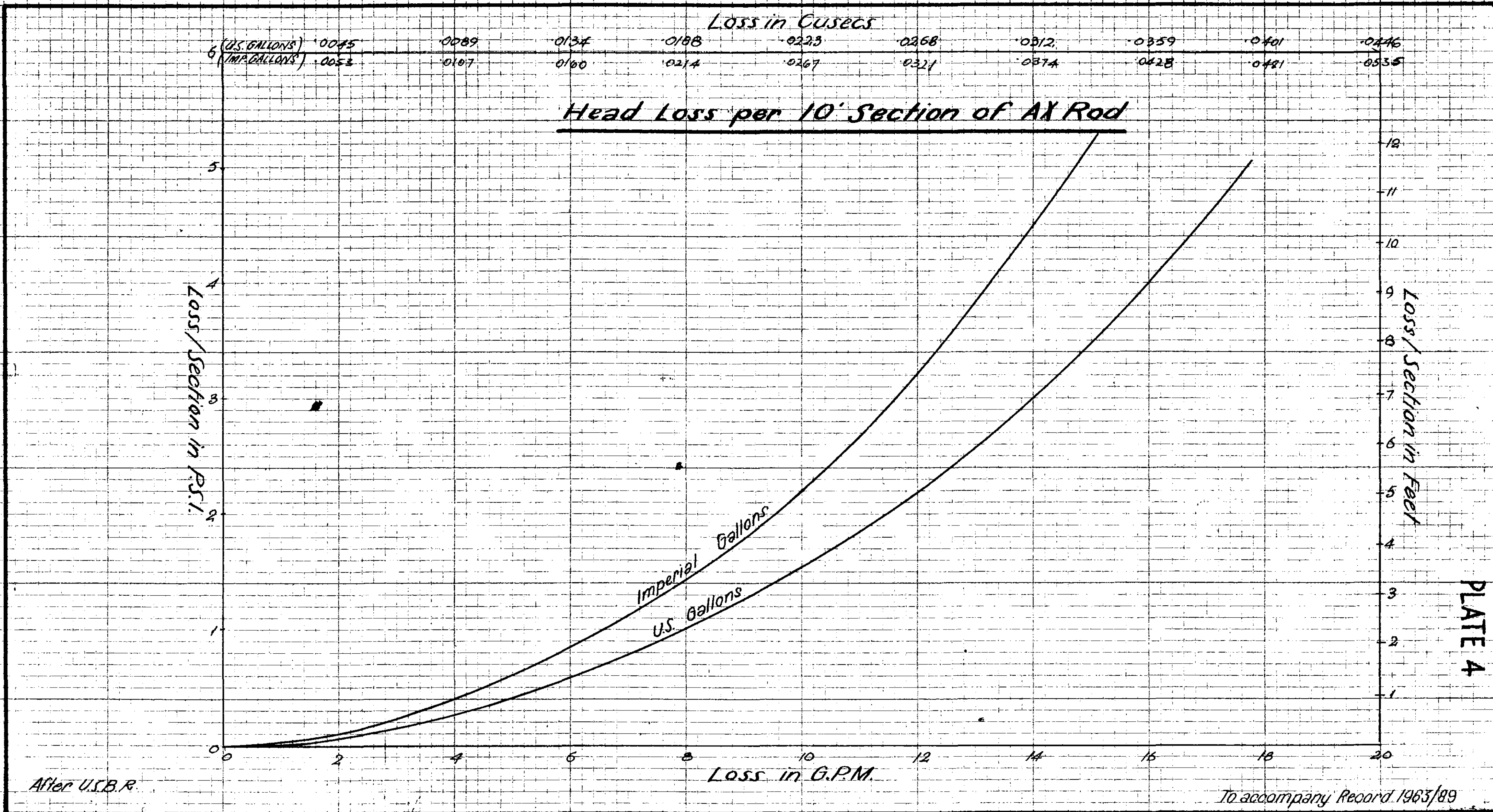
To accompany Record 1963/89



After U.S.B.R.

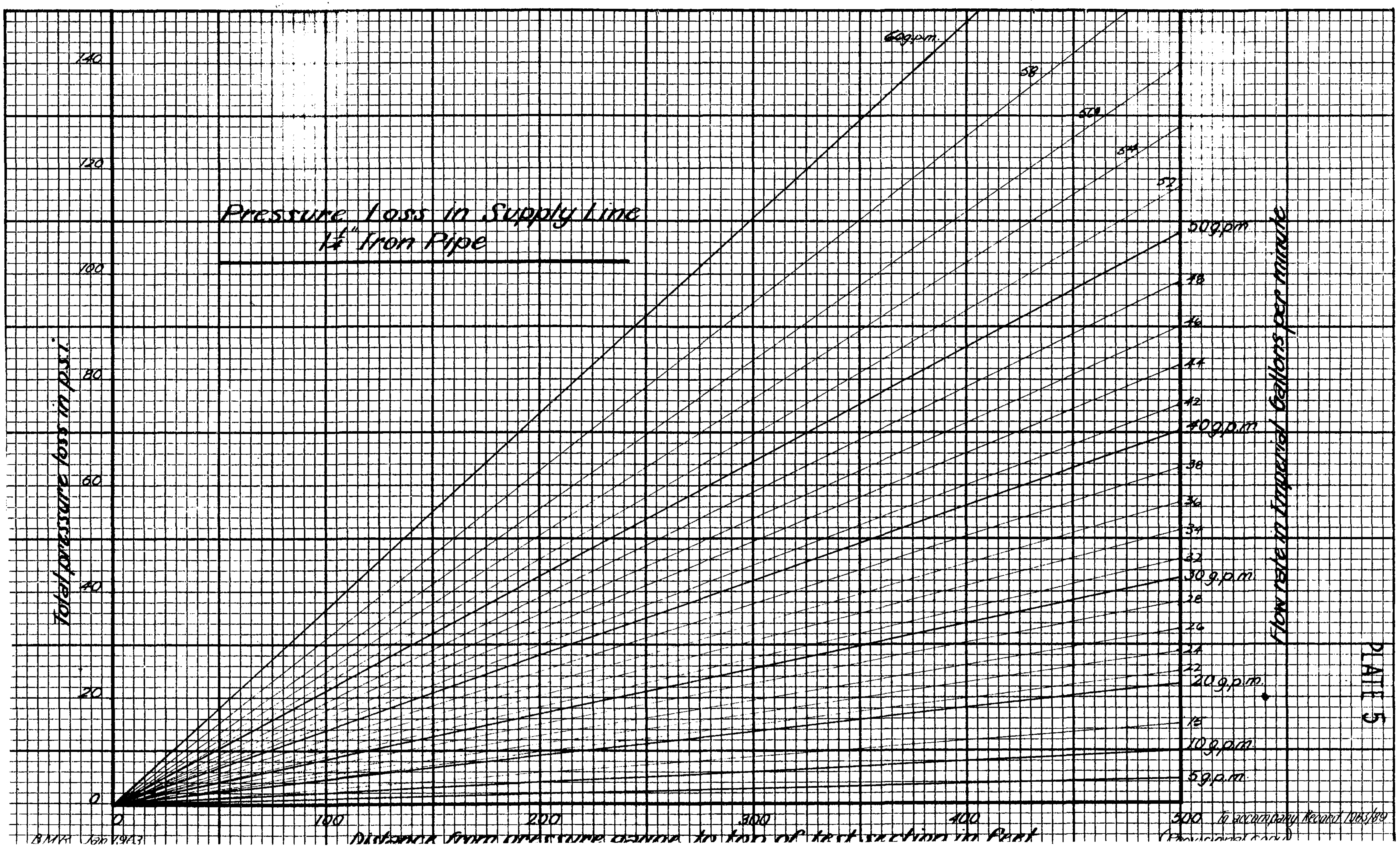
To accompany Record 1963/89

PLATE 3



To accompany Record 1963/89

PLATE 4


Pressure Loss in Supply Line
1¼" Iron Pipe
Total pressure loss in p.s.i.
0
20
40
60
80
100
120
140
0
100
200
300
400
500
Distance from pressure gauge to top of test section in feet
Flow rate in Imperial Gallons per minute
60g.p.m.
58
56
54
52
50g.p.m
48
46
44
42
40g.p.m
38
36
34
32
30g.p.m
28
26
24
22
20g.p.m.
15
10g.p.m.
5g.p.m.
To accompany Record 1963/89
B.M.G. Jan 1963
PLATE 5

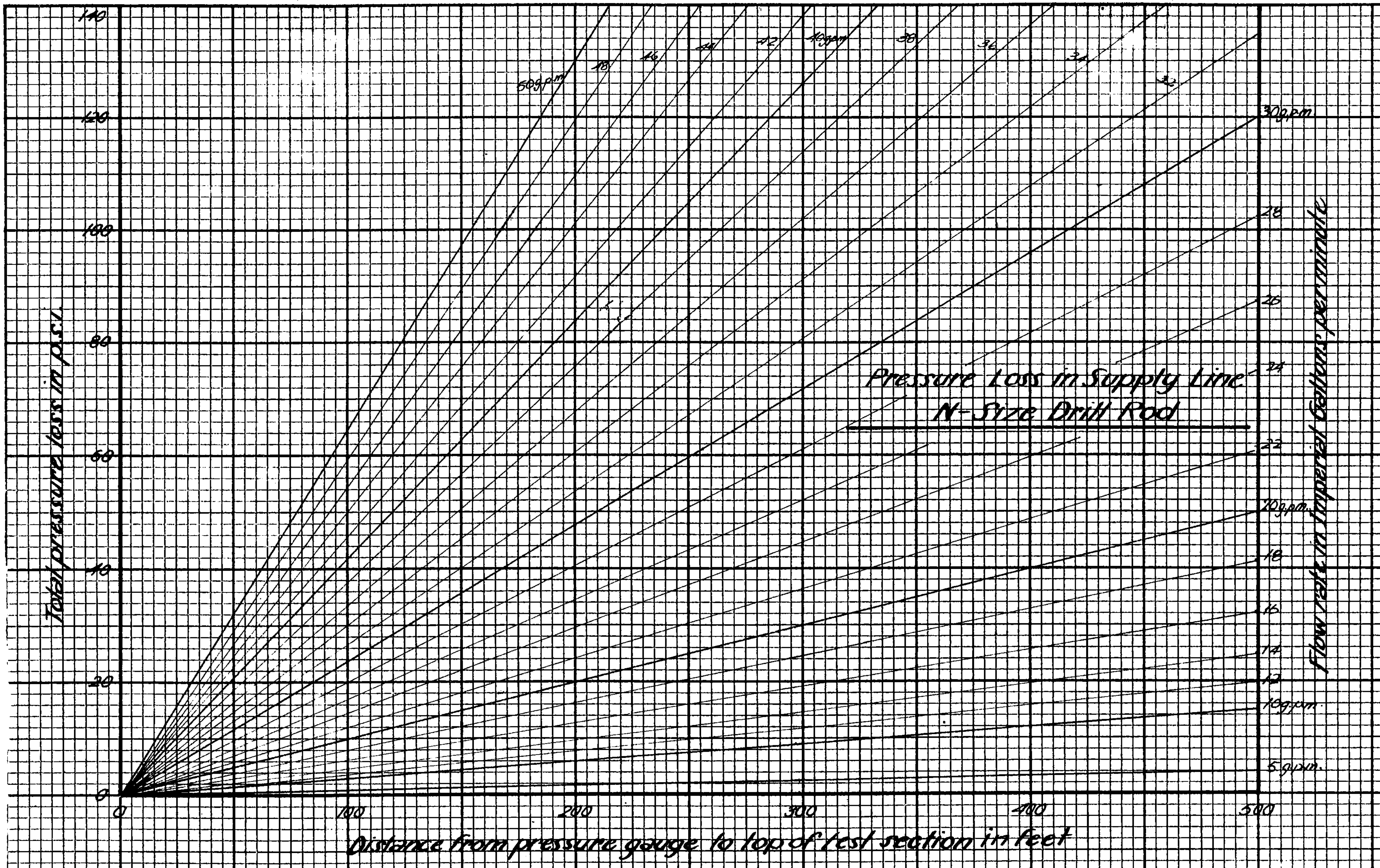
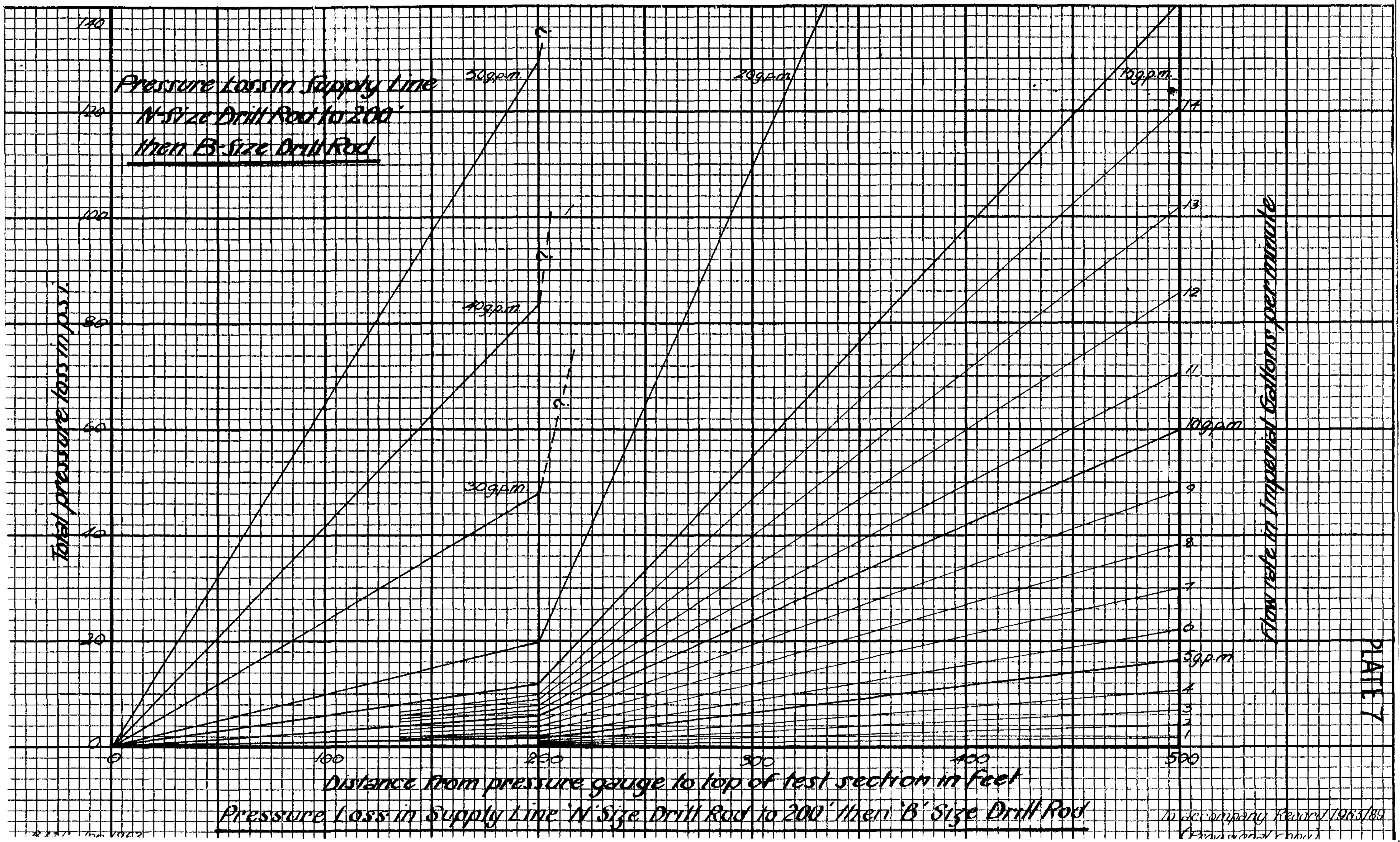


PLATE 6

B.M.R. Feb 1963

To accompany Record 1963/89

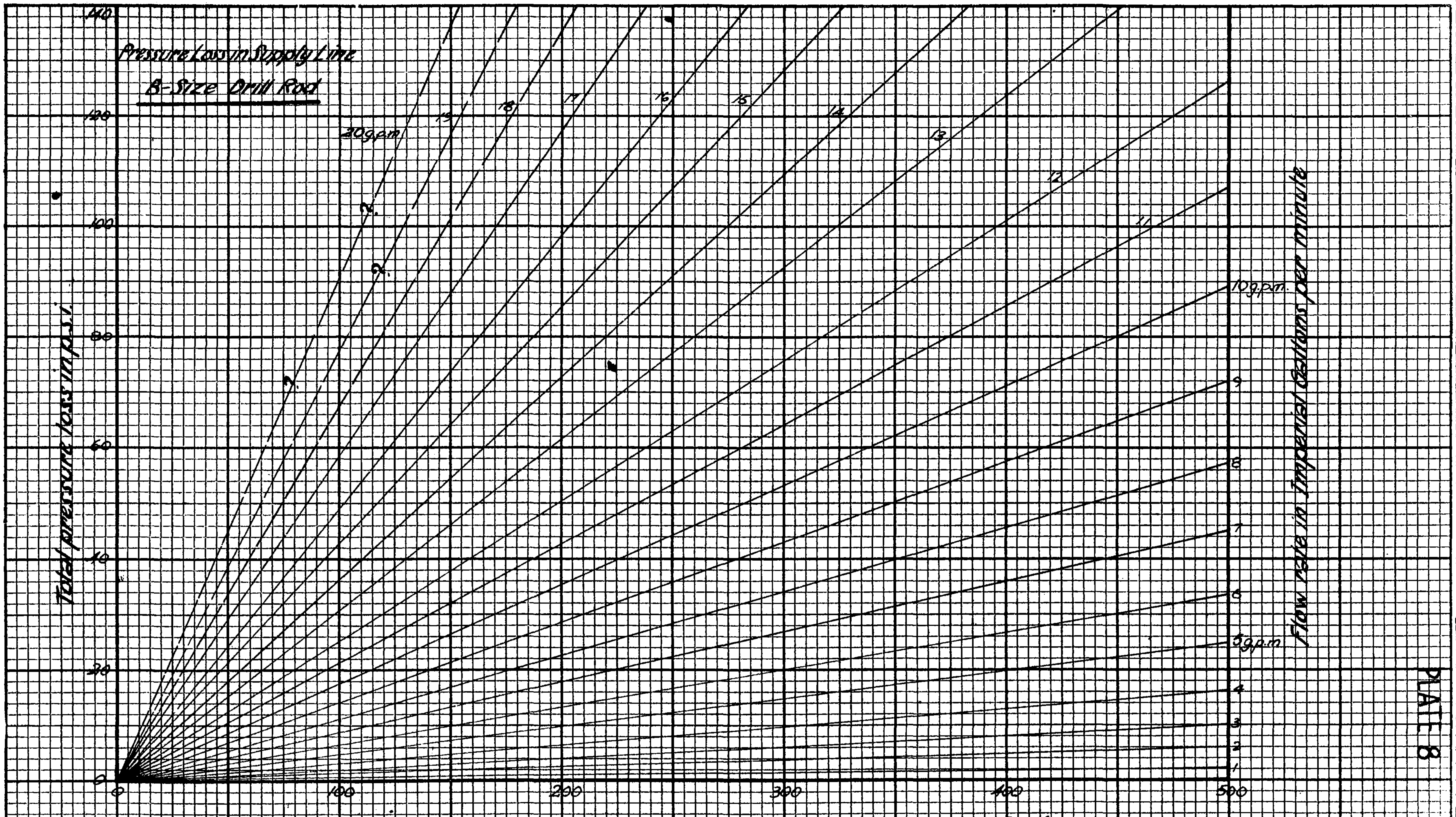
(Provisional copy)



Pressure Loss in Supply Line 'N' Size Drill Rod to 200' then 'B' Size Drill Rod

To accompany Record 1963/89

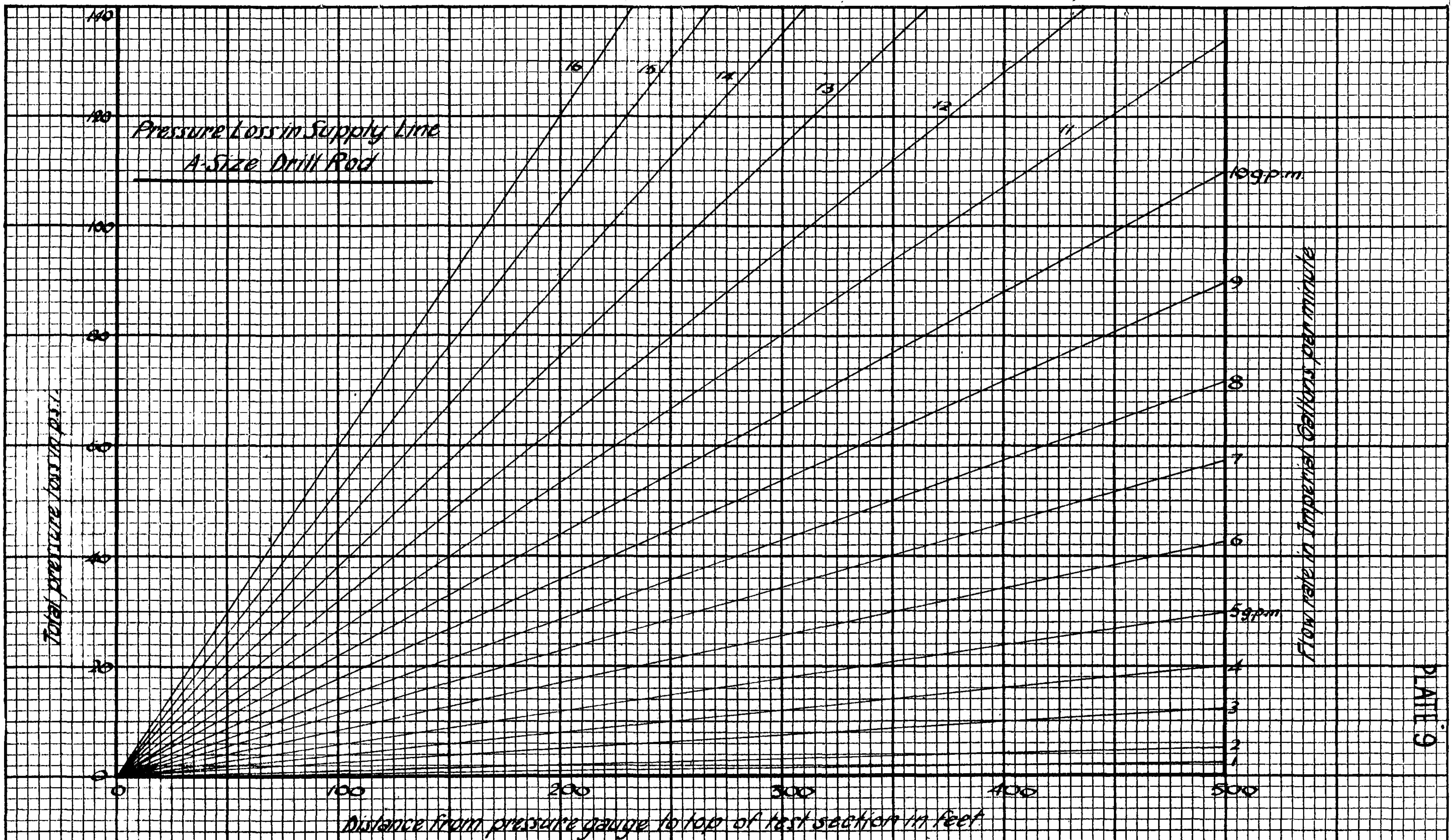
PLATE 7



Pressure Loss in Supply Line 'B' Size Drill Rod

PLATE 8

To accompany Record 1963/89



Pressure Loss in Supply Line 'A' Size Drill Rod

To accompany Record 1965/89

PLATE 9

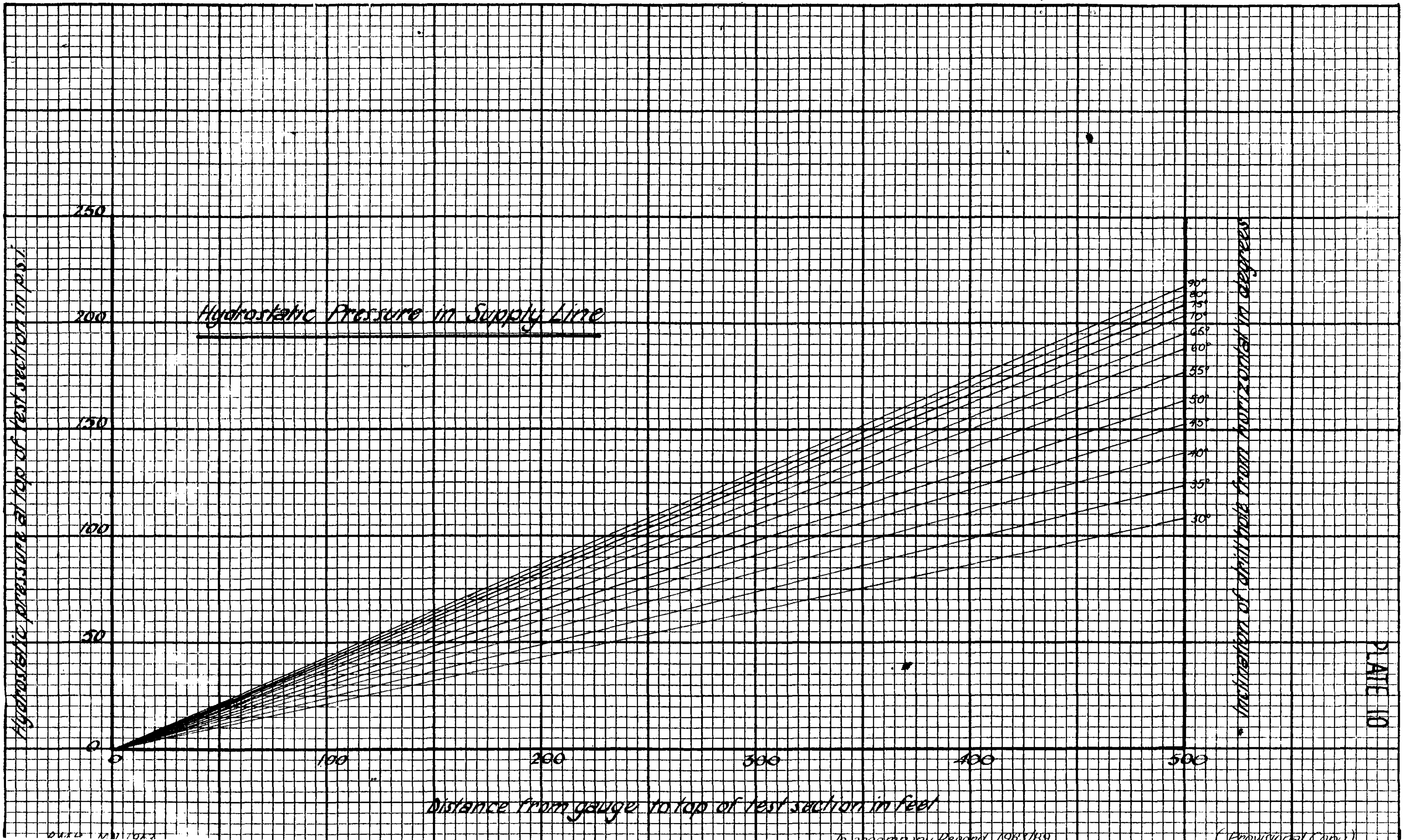
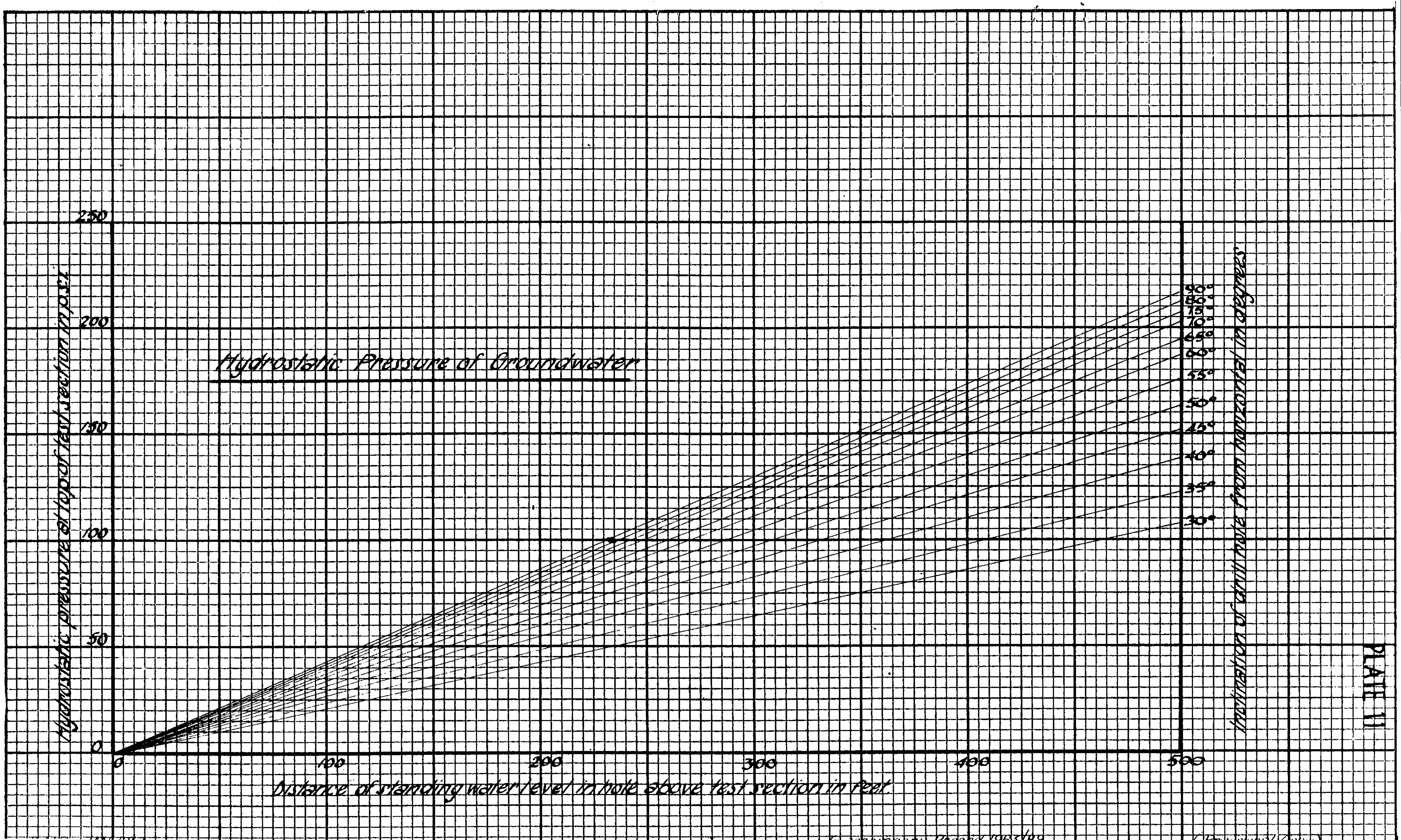


PLATE 10

To accompany Record 1963/89

(Provisional Copy)



To accompany Record 1963/89

(Provisional Copy)

PLATE 11