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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

ANALYSIS OF HYDRAULIC TESTS IN HOT CREEK VALLEY, NEVADA

June 1970

Open-file report

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for the

Nevada Operations Office
U.S. Atomic Energy Commission

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ANALYSIS OF HYDRAULIC TESTS IN HOT CREEK VALLEY, NEVADA

By

George A. Dinwiddie

ABSTRACT

This report, prepared in support of the U.S. Atomic Energy Commission's underground nuclear testing program in central Nevada, presents an analysis of data obtained during hydraulic tests in exploratory holes, Hot Creek Valley, Nevada. The analysis is focused on determining variations in hydrostatic head in the vertical section; transmissivity, hydraulic conductivity, storage coefficients, and velocity of ground-water movement in selected intervals; and inflow to a theoretical chamber.

Hole UCe-17 penetrated alluvium, welded tuff, zeolitized bedded tuff, and tuffaceous sediments. The composite water level was 161.0 meters below land-surface datum. In the tested intervals from which the data were adequate for analysis, transmissivity ranged from 8.47×10^{-4} to an estimated 8.76 m^3pd per m (cubic meters per day per meter); hydraulic conductivity ranged from 1.39×10^{-5} to an estimated 1.44×10^{-1} m^3pd per m^2 (cubic meters per day per square meter); storage coefficients ranged from 6.26×10^{-7} to 5.65×10^{-3}; and velocity ranged from 9.27×10^{-7} to an estimated 1.44×10^{-2} mpd (meters per day).

Hole UCe-18 penetrated alluvium, lake beds and gypsum, rhyolite, and bedded tuff. The composite water level was 59.8 meters below land-surface datum. Only the data from the interval 1,237.8 to 1,277.4 meters were adequate for analysis; transmissivity was 4×10^{-3} m^3pd per m; hydraulic conductivity was 1×10^{-4} m^3pd per m^2; storage coefficient was 6.1×10^{-7}; and velocity was 5×10^{-6} mpd. Specific capacity after 9 hours of pumping was 55.5 m^3pd per m of drawdown.

Hole UCe-20 penetrated alluvium, welded tuff, and tuffaceous conglomerate. The composite water level was 65.5 meters below land-surface datum. In the interval 1,652.4 to 1,670.7 meters below land surface the static water level was also 65.5 meters below land surface, and the hydraulic potential decreased both above and below this zone. In the tested intervals from which the data were adequate for analysis, transmissivity ranged from 2.48×10^{-4} to 43.8 m^3pd per m; hydraulic conductivity ranged from 1.18×10^{-5} to 2.05 m^3pd per m^2; storage coefficients ranged from 4.67×10^{-7} to 6.10×10^{-3}; and velocity ranged from 5.9×10^{-7} to 1×10^{-1} mpd.

Inflow to a theoretical cylindrical chamber 3.66 meters in diameter and at a depth of from 1,524.4 to 1,533.5 meters below land surface in UCe-20 was computed using a leaky artesian, constant-drawdown formula. Because of many variables and unique conditions, the computation can be considered only as an approximation. The inflow to the theoretical chamber probably would be about 14 cubic meters per day after an elapsed inflow time of about 70 days.

Hole HTH-1 penetrated alluvium, welded tuff, and tuffaceous sediments. The composite water level was 168.6 meters below land-surface datum. In the tested intervals from which the data were adequate for analysis, transmissivity ranged from 1.9×10^{-3} to an estimated 16.4 m^3pd per m; hydraulic conductivity ranged from 6.2×10^{-5} to an estimated 3.6×10^{-1} m^3pd per m^2; storage coefficients ranged from 6.1×10^{-7} to 6.1×10^{-3}; and velocity ranged from 1.2×10^{-5} to an estimated 7.2×10^{-2} mpd. Specific capacity after about 7 days of pumping was about 121 m^3pd per m of drawdown.

INTRODUCTION

Hydraulic testing and sampling in wells in central Nevada is done to: 1) supplement and improve knowledge of the general hydrologic environment of the area for better prediction of direction and velocity of groundwater movement, 2) determine the water/rock chemistry and radiochemistry for improved understanding of radionuclide transport characteristics and for evaluation of the effect and distribution of shot-produced contaminants, 3) determine certain hydraulic characteristics for engineering and design of chambers in specific lithologic zones, and 4) provide information about water supplies for drilling, construction projects, and camp sites. This report presents an analysis of the basic data obtained during hydraulic tests in Hot Creek Valley (fig. 1). The analysis consists of determining

hydrostatic head distribution in the vertical section; distribution of water quality in the vertical section; transmissivity, hydraulic conductivity, storage coefficients, and velocity of ground-water movement in selected intervals; and inflow to a theoretical chamber. Discussion of significance of water quality in Hot Creek Valley will be available in a later report.

Inflatable straddle packers were used to isolate specific intervals of the holes. Intervals were tested by injecting or swabbing water through tubing and observing the rate of reaction of the water level. Intervals were selected according to apparent characteristics of hydrology, lithology, and hole conditions as interpreted from geologic reports and downhole geophysical logs.

Hydraulic tests in deep exploratory holes in central Nevada were performed by the Hydrologic Task Force under the direction of George A. Dinwiddie, U.S. Geological Survey, Task Force Leader. The Task Force consists of personnel from the U.S. Geological Survey, Water Resources Division; the Desert Research Institute, Center for Water Resources Research, University of Nevada System; and Teledyne Isotopes, Palo Alto Laboratories. During the hydraulic tests, personnel from these three organizations comprising the Hydrologic Task Force worked as a group to perform the required duties.

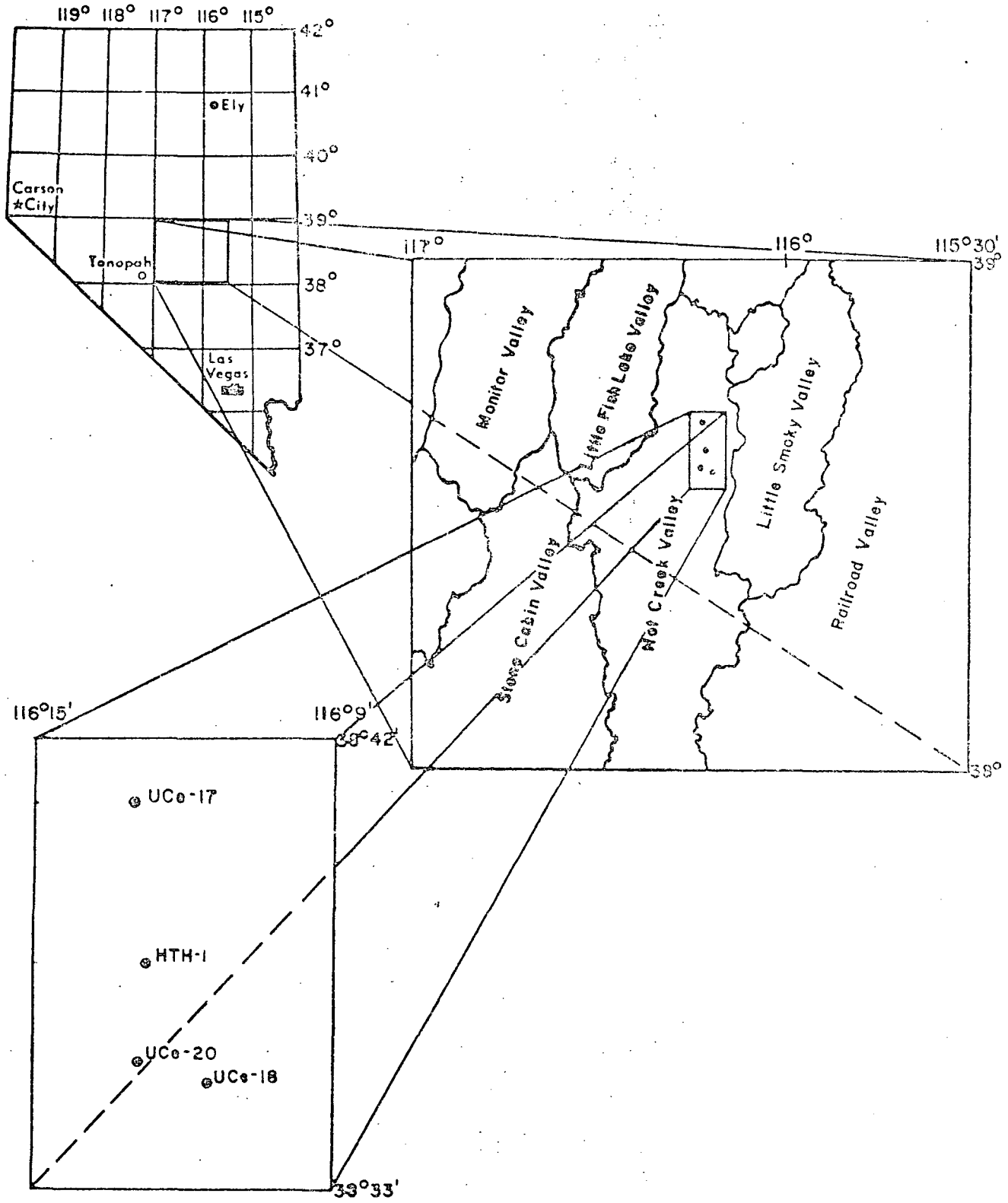

Figure 1.--Map of Nevada showing general locations of central Nevada, Hot Creek Valley, and wells described in this report

METHOD OF ANALYSIS

A type-curve method for determining the transmissivity of an aquifer that is applicable to testing of selected intervals in deep wells was introduced by Cooper and others (1967). This analysis involves an instantaneous charge of water to a well. The type curves (fig. 2) are derived by plotting H/H_o versus $\beta = Tt/r_c^2$ (a dimensionless time parameter) for values of $\alpha = r_s^2 S/r_c^2$ where

H_o = water level in tubing above initial head in aquifer immediately after injection, in meters (m)

H = water level in tubing above initial head in aquifer, in meters, at time, t, in days

T = transmissivity, in cubic meters per day per meter (m^3pd per m)

r_c = radius of injection tubing, in meters

r_s = radius of open hole, in meters

S = storage coefficient.

Once a value of T is obtained, hydraulic conductivity, K, can be calculated by the equation

$$K = T/b$$

where K is in cubic meters per day per square meter (m^3pd per m^2) and b = thickness of the tested interval, in meters. Velocity of ground-water movement (v) can then be calculated by the equation

$$v = KI/\theta$$

where v is in meters per day (mpd)

I = ground-water gradient, in meters per meter, and

θ = effective porosity, in percent.

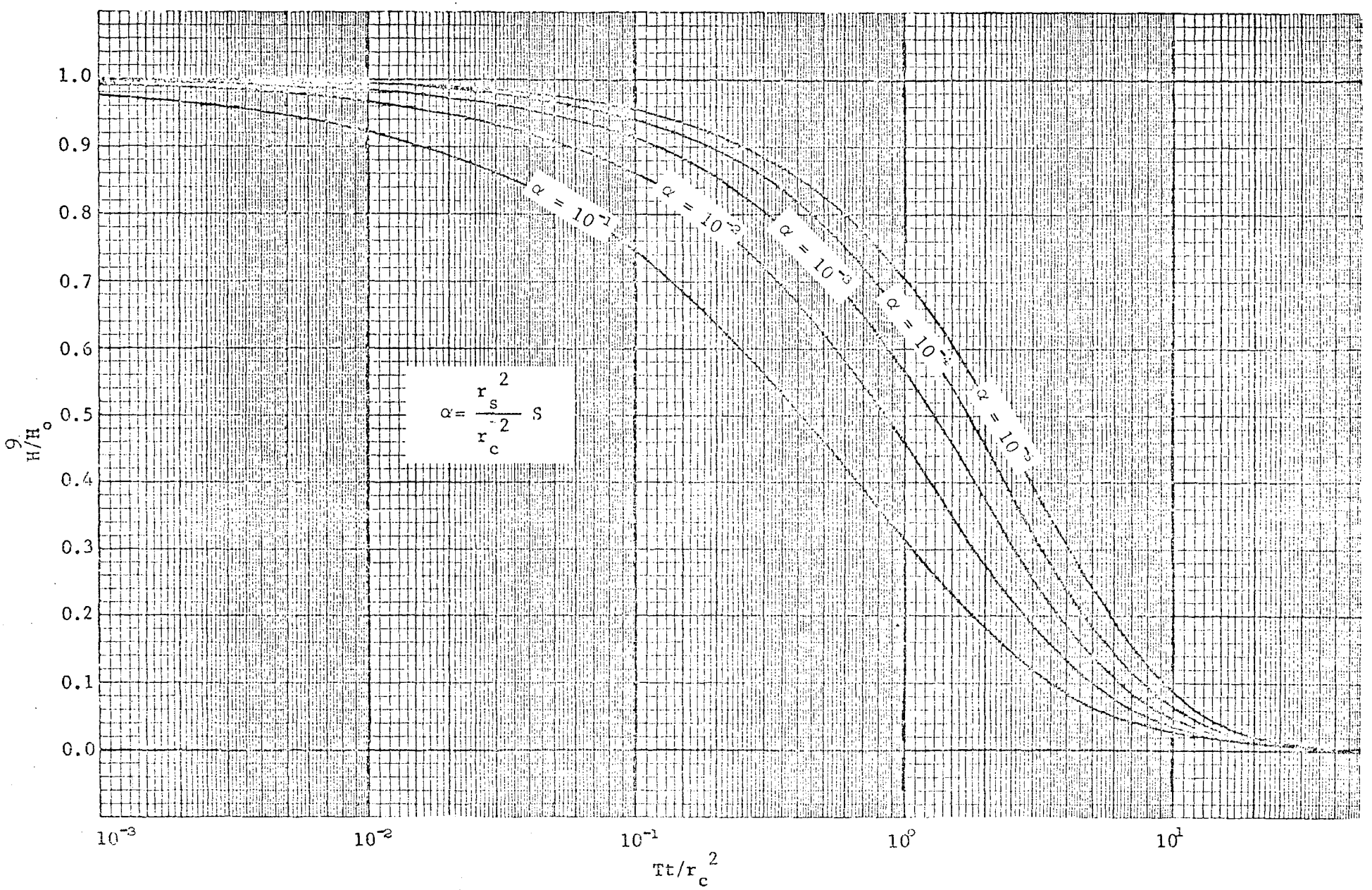

Figure 2.--Type curves for instantaneous charge in well of finite diameter.

HYDRAULIC GRADIENT

The hydraulic gradient must be known in order to solve the velocity equation. Average values of hydraulic potential of comparable depth intervals in holes UCe-17, UCe-18, and UCe-20 were used in a 3-point solution to determine the gradient in the lower (bedrock) system. The results of this 3-point solution indicate a gradient of about 1 meter per 100 meters to the southwest. Average values of hydraulic potential in holes UCe-11, UCe-17, and HTH-1 were used in a 3-point solution to determine the gradient in the upper (alluvium) system. The results of this 3-point solution indicate a gradient of about 4 meters per 100 meters to the southeast.

HOLE UCe-17

Hole UCe-17, at coordinates N. 1,430,622 ft and E. 628,172 ft, Nevada coordinate system, central zone, Nye County, Nevada, penetrated alluvium, welded tuff, zeolitized bedded tuff, and tuffaceous sediments. The land-surface elevation at this site is 1,995.4 meters above mean sea level.

Hydrostatic head distribution

The greatest hydraulic potential was measured in the interval from 239.3 to 561.0 meters below land surface. The static water level in this interval was about 145 meters below land surface during testing. The hydraulic potential decreases below this interval. The static water level in the interval 957.0 to 1,018.0 meters was 268.9 meters below land surface. The static water level in the interval 2,056.4 to 2,117.4 meters was about 351 meters below land surface.

Tracejector survey

Significant results were obtained from tracejector surveys under both pumping and static conditions. The results indicate a definite potential for downward flow. Under static conditions, vertical flow in the borehole was downward at a rate between 110 and 150 m^3pd to a point at about 1,445 meters below land-surface datum. At this depth, most of the flow went into the formation. Below this depth, some downward flow (less than 33 m^3pd) and continual loss to the rock was observed. There was no measurable flow in the borehole below a depth of 1,957 meters.

A tracejector survey made while pumping water at a rate of about 870 m^3pd indicates that most of the water came from the intervals 239.3 to 279.0 meters; 539.6 to 561.0 meters, and 1,443.6 to 1,446.6 meters (fig. 3).

Specific capacity

The well was pumped for a short time before the tracejector survey was made. The pump intake was at 357 meters below land surface, the average discharge was about 925 m^3pd, and the drawdown was 141.54 meters after 13 hours of pumping. Therefore, the specific capacity during this test was about 6.5 m^3pd per m of drawdown.

Hydraulic characteristics

The analyses of data from injection into individual intervals in hole UCe-17 are presented in figures 4-12. The following parameters were constant for all the intervals tested in hole UCe-17:

r_c = 3.02 cm

b = 61 m

I = 0.01 m per m.

Variable parameters are shown on the figures.

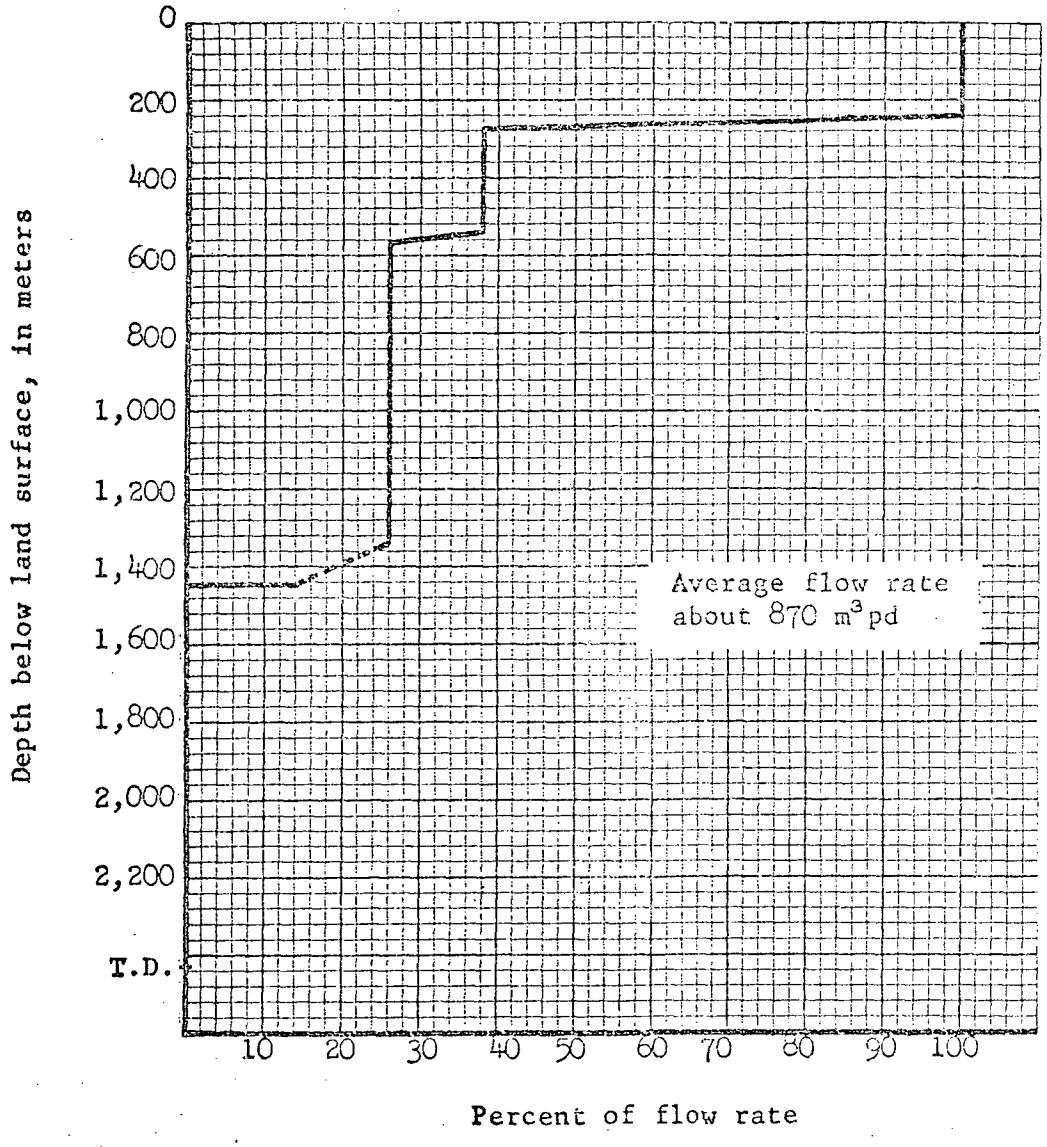

Figure 3.--Tracejector survey of hole UCe-17, Hot Creek Valley, Nevada, while pumping.

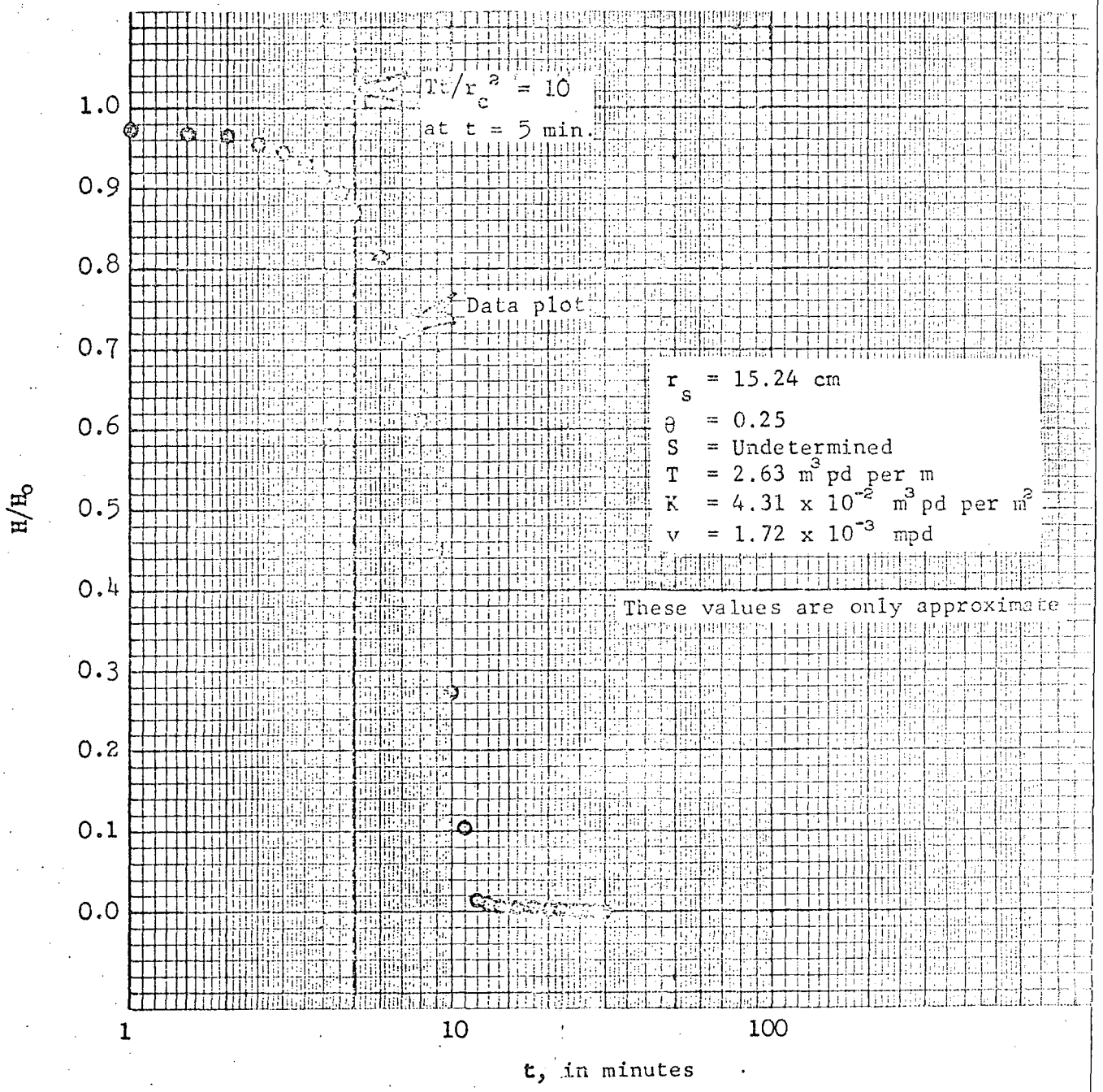

Figure 4.--Injection test of interval 957.0 to 1,018.0 m, hole UCe-17, Hot Creek Valley, Nevada.

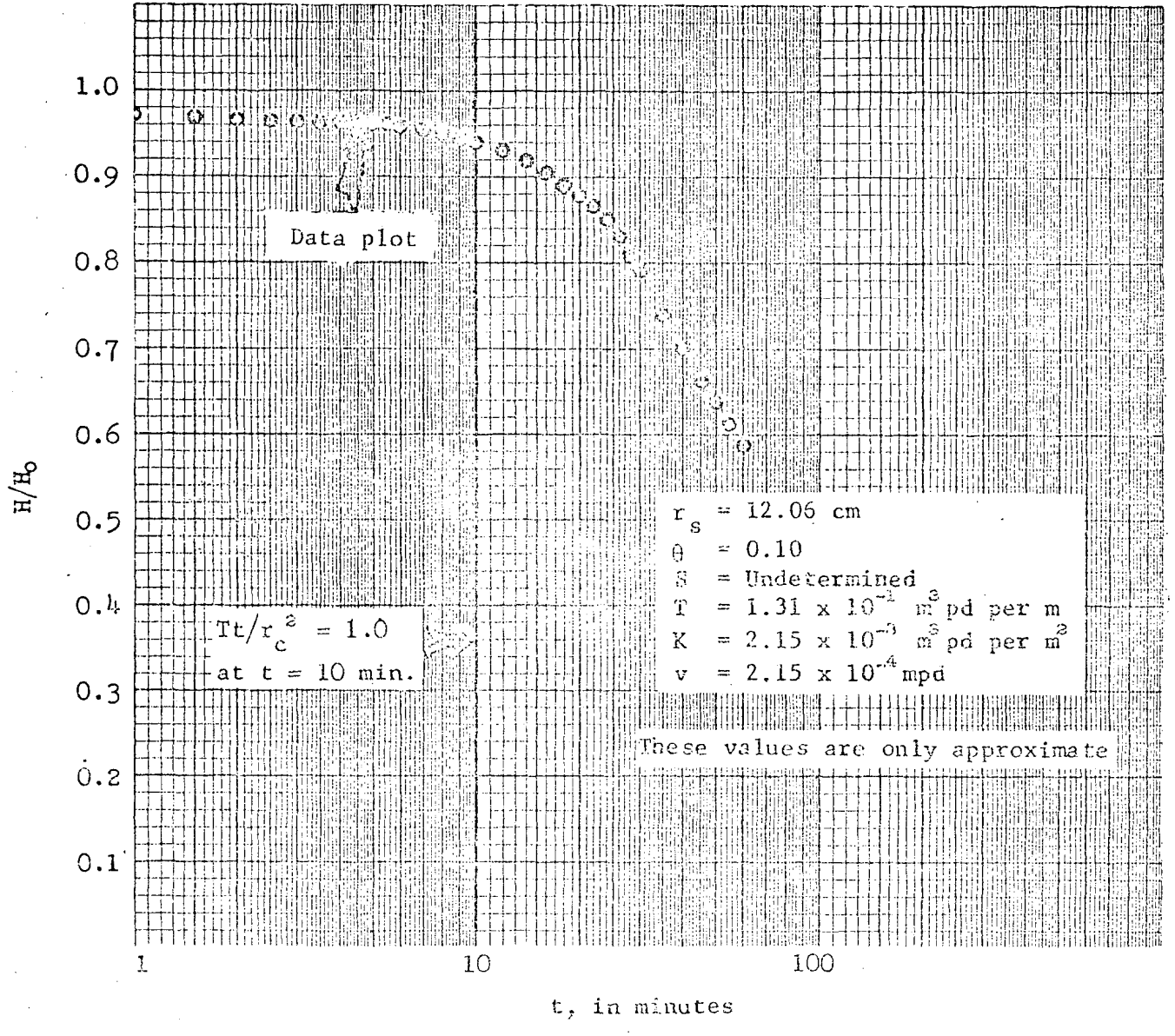

Figure 5.--Injection test of interval 1,367.7 to 1,428.7 m, hole UCe-17, Mot Creek Valley, Nevada.

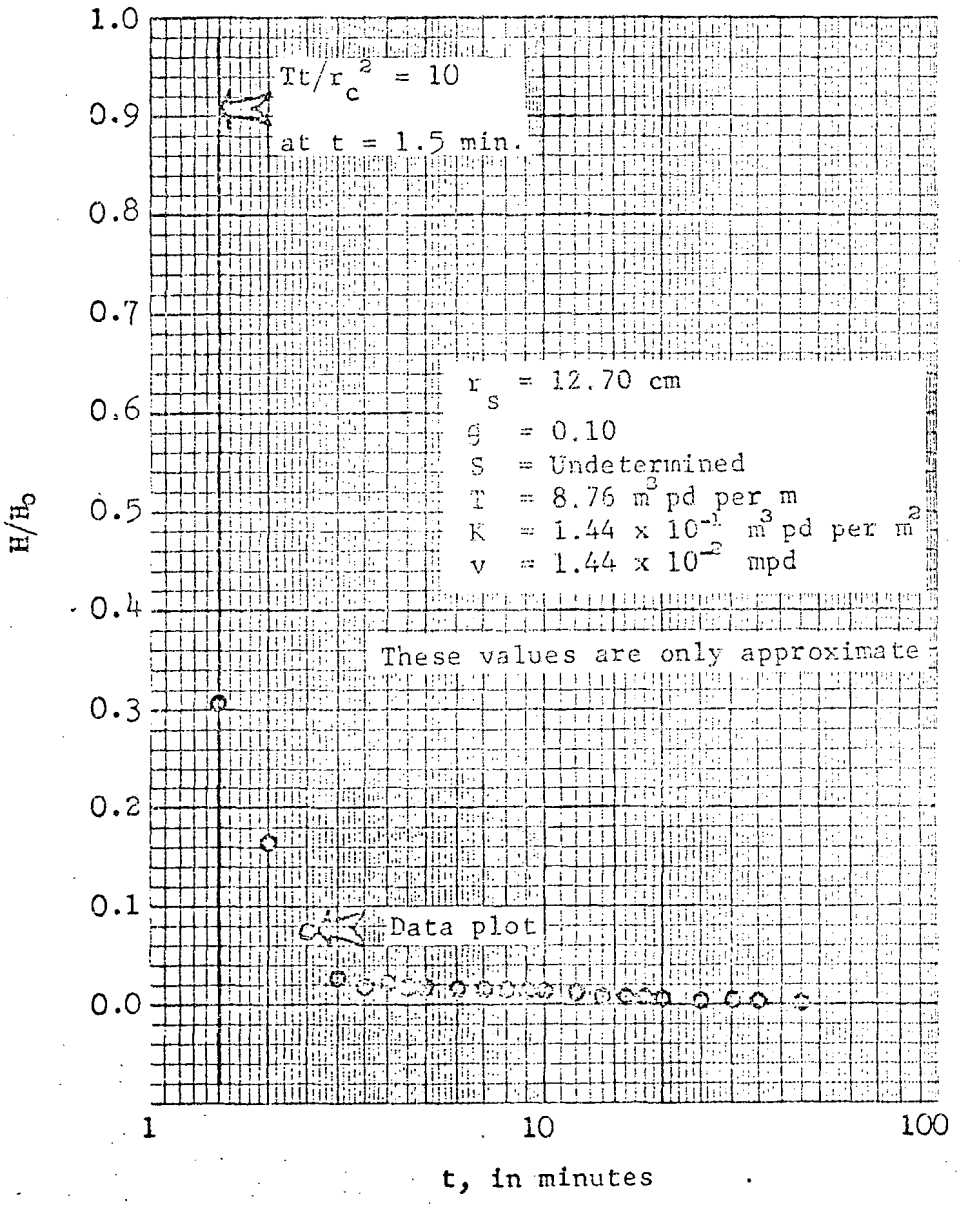

Figure 6.--Injection test of interval 1,408.5 to 1,469.5 m, hole UCe-17, Hot Creek Valley, Nevada.

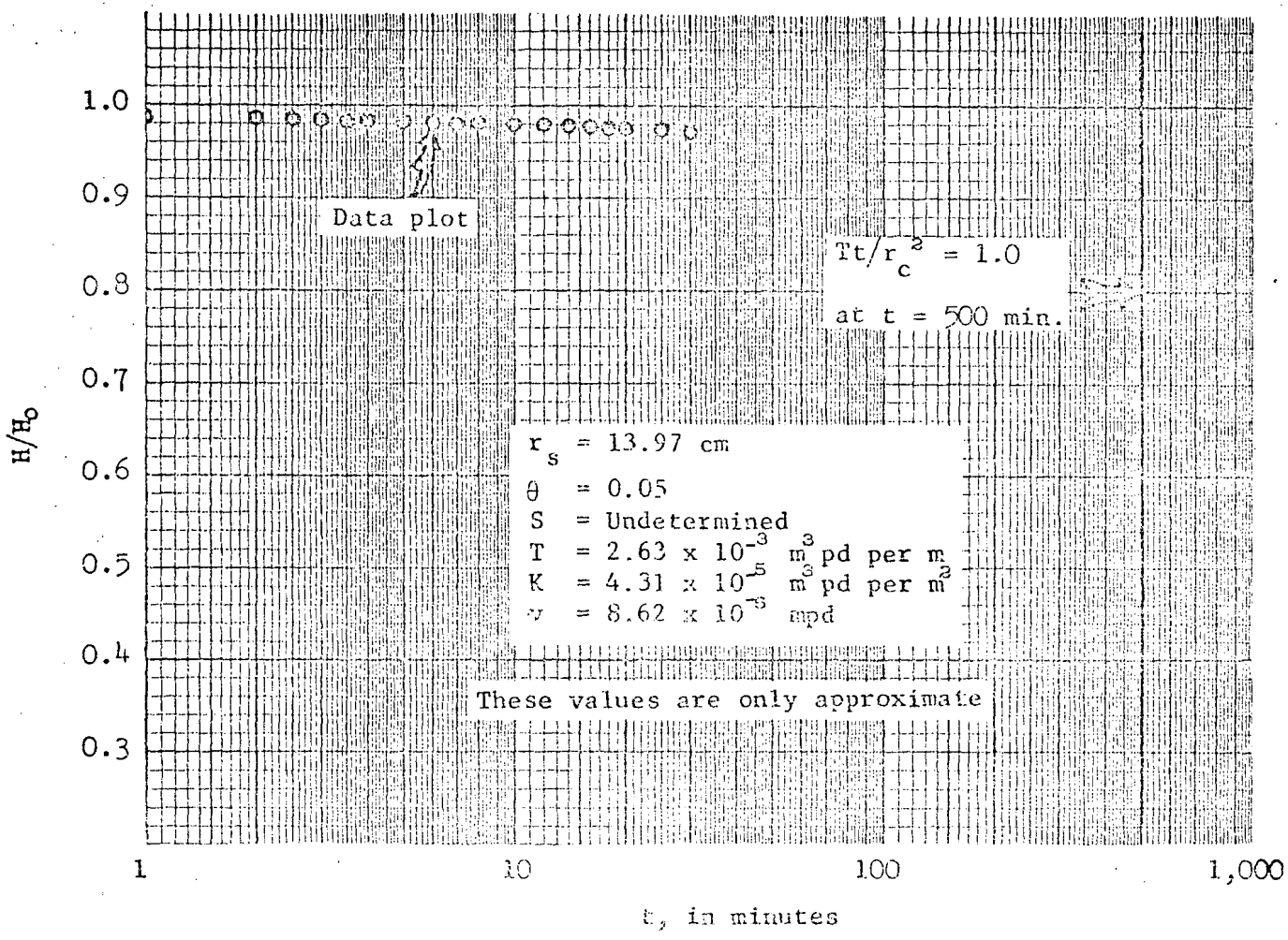

Figure 7.--Injection test of interval 1,597.6 to 1,658.6 m, hole UCe-17, Hot Creek Valley, Nevada.

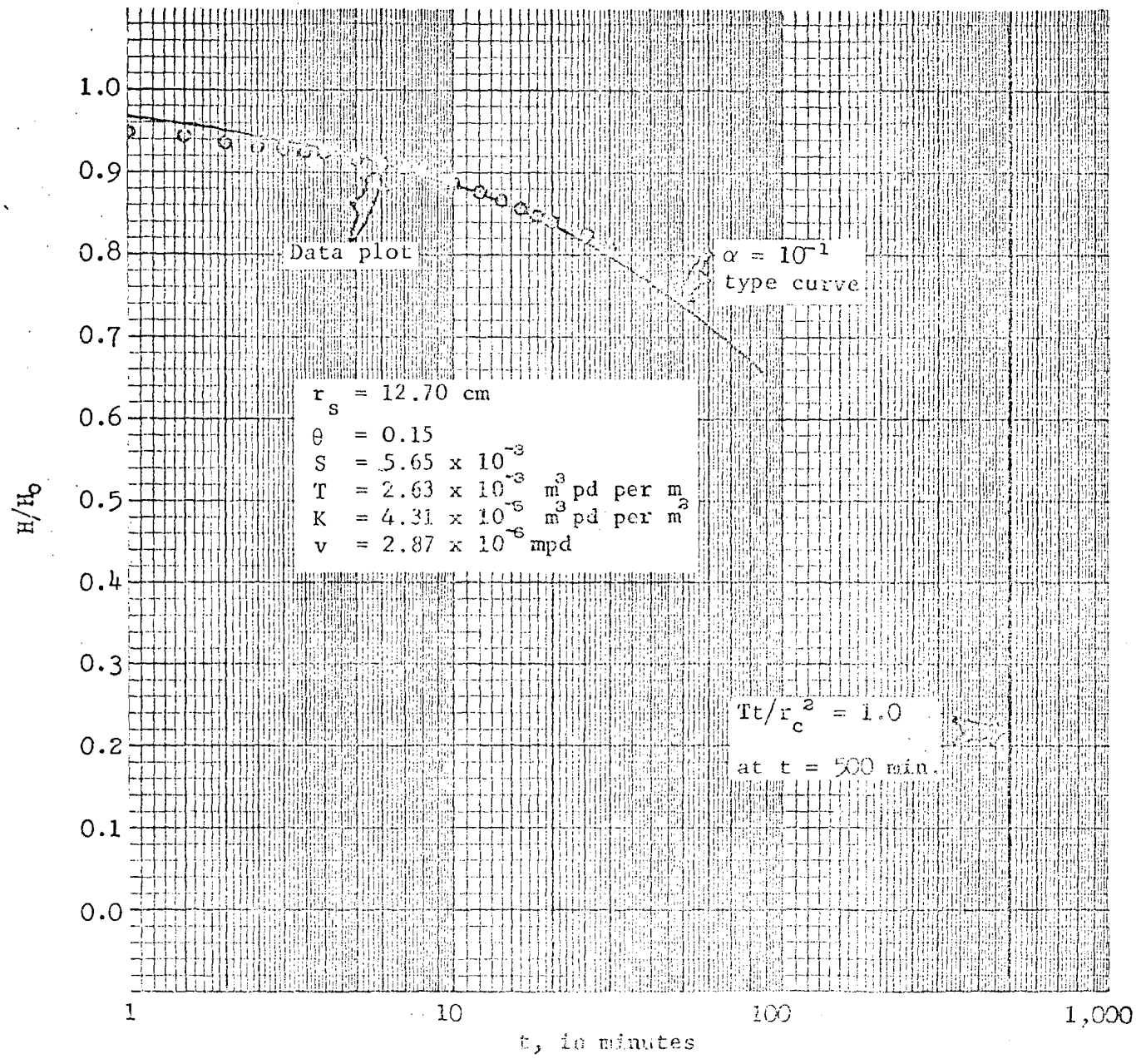

Figure 8.--Injection test of interval 1,868.9 to 1,929.9 m,

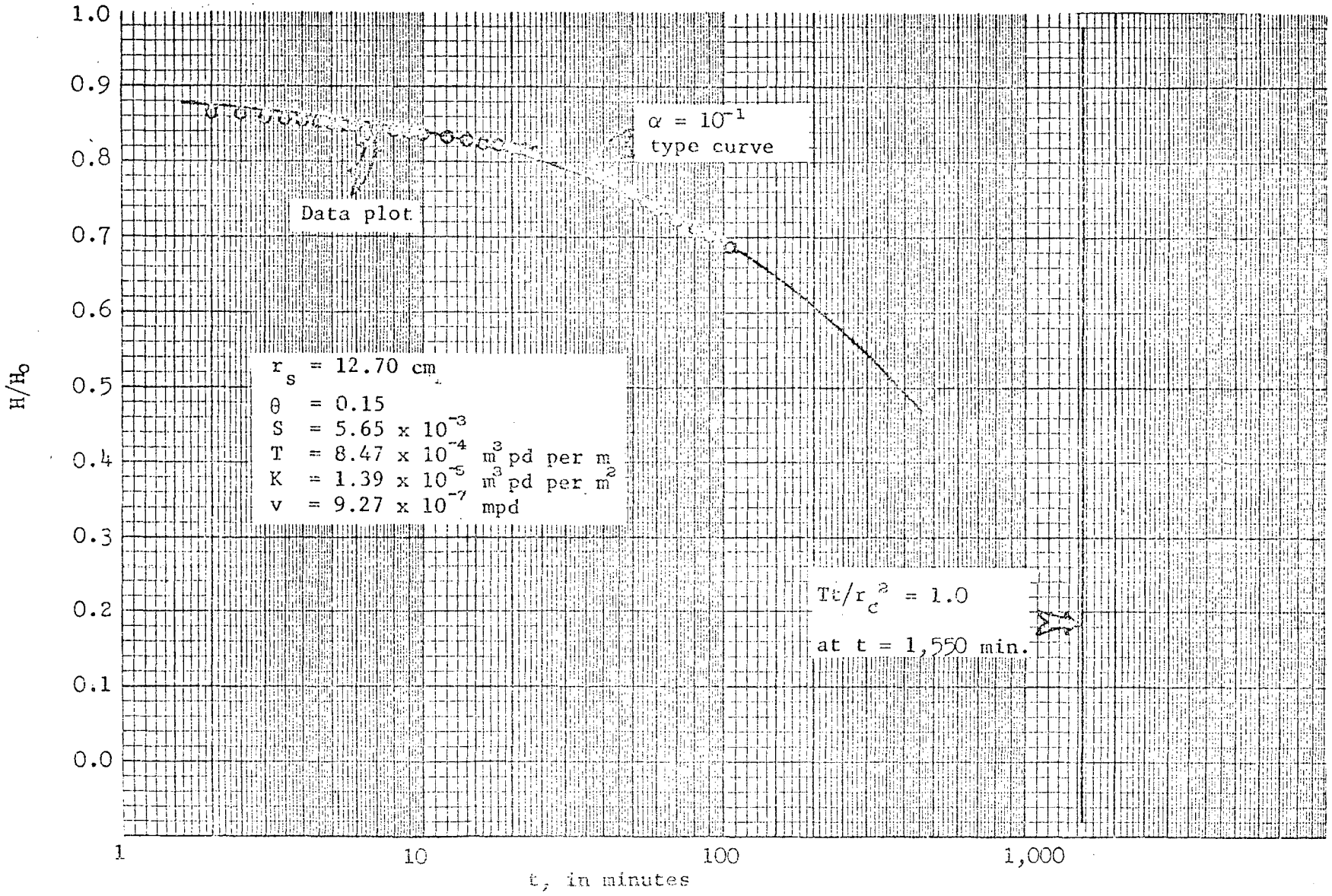

Figure 9.--Injection test of interval 1,960.4 to 2,021.4 m, hole UCe-17, Hot Creek Valley, Nevada.

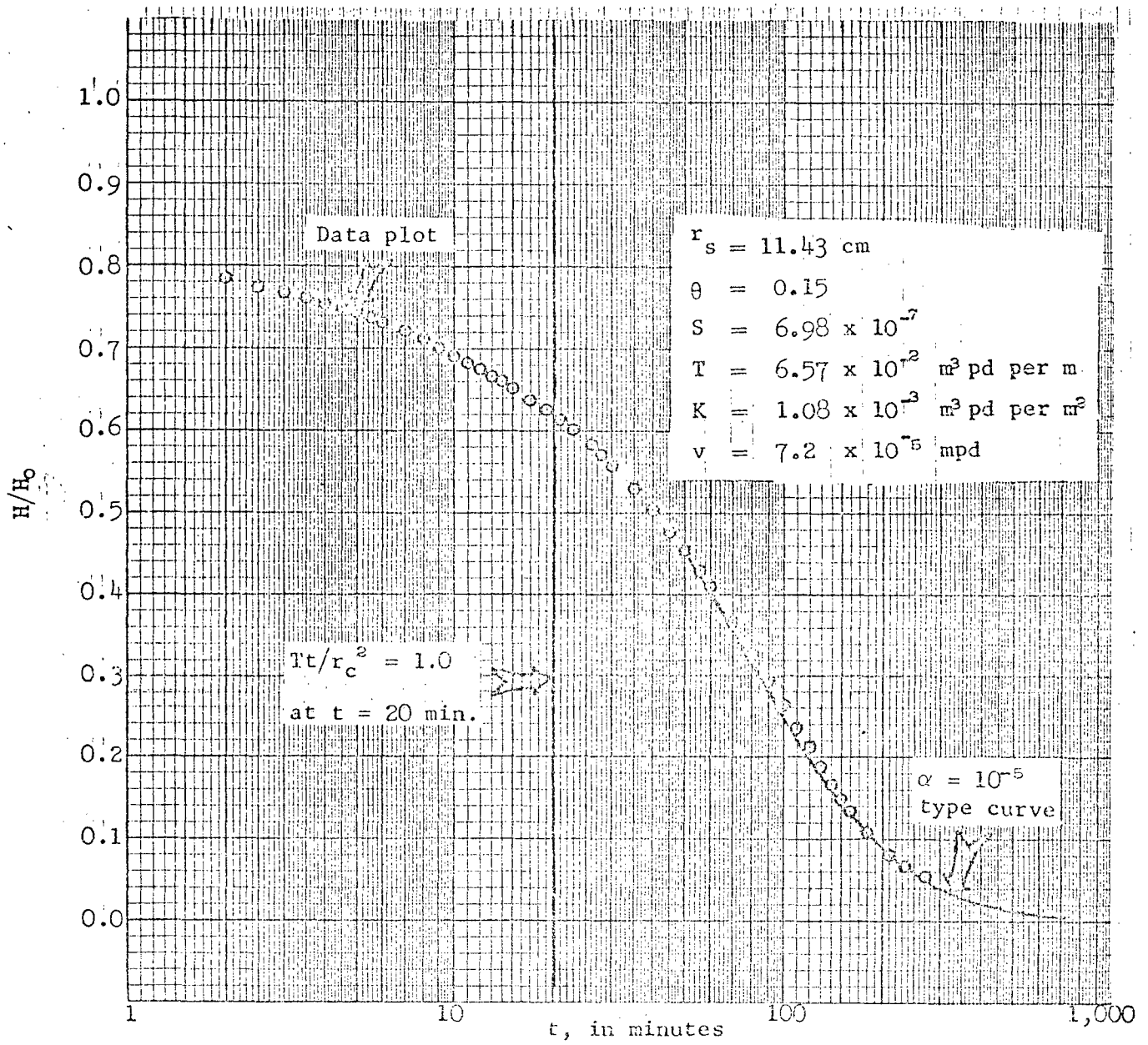

Figure 10.--Injection test of interval 2,056.4 to 2,117.4 m, hole UGe-17, Hot Creek Valley, Nevada.

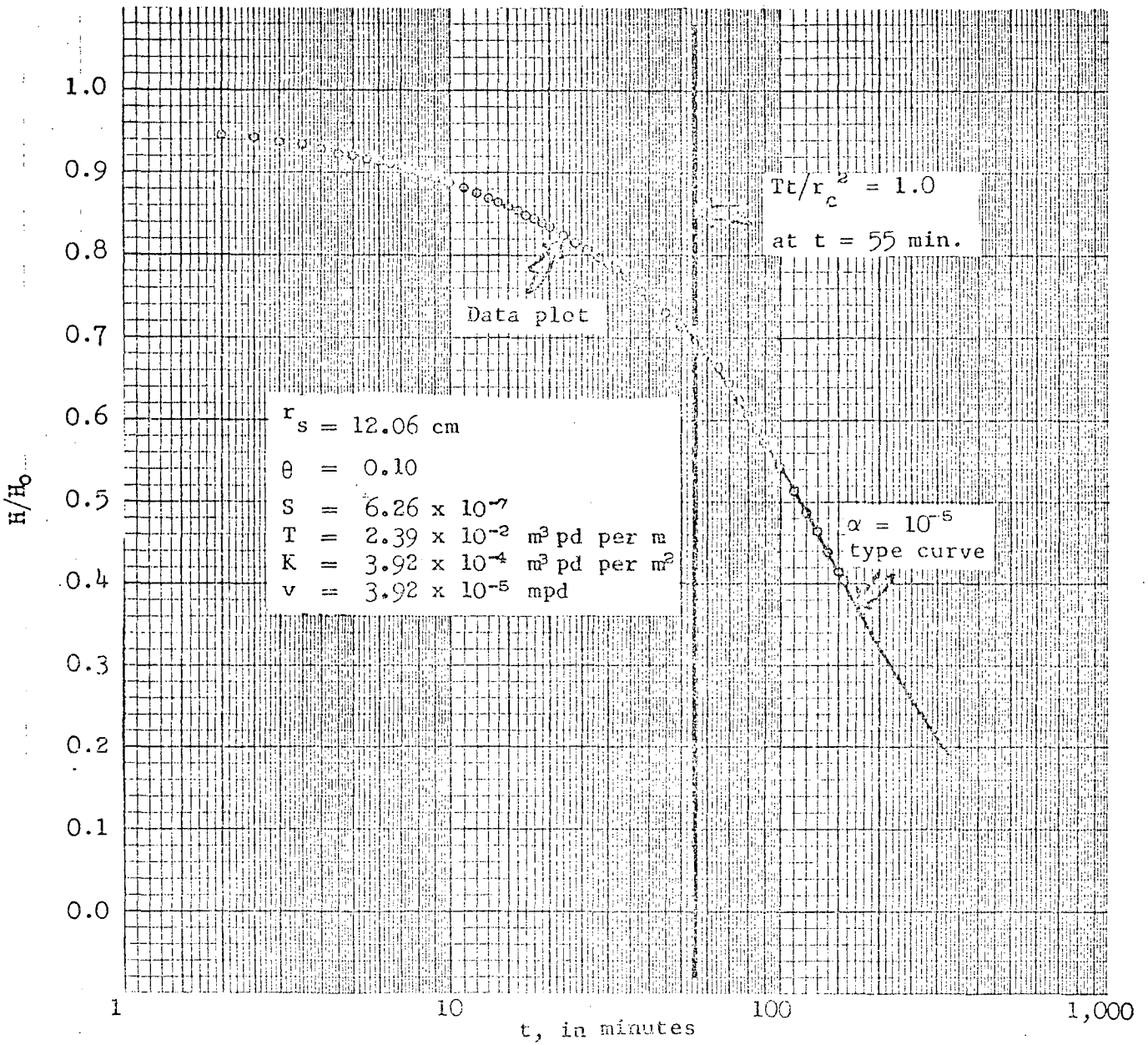

Figure 11.--Injection test of interval 2,149.4 to 2,210.4 m, hole UCe-17, Hot Creek Valley, Nevada.

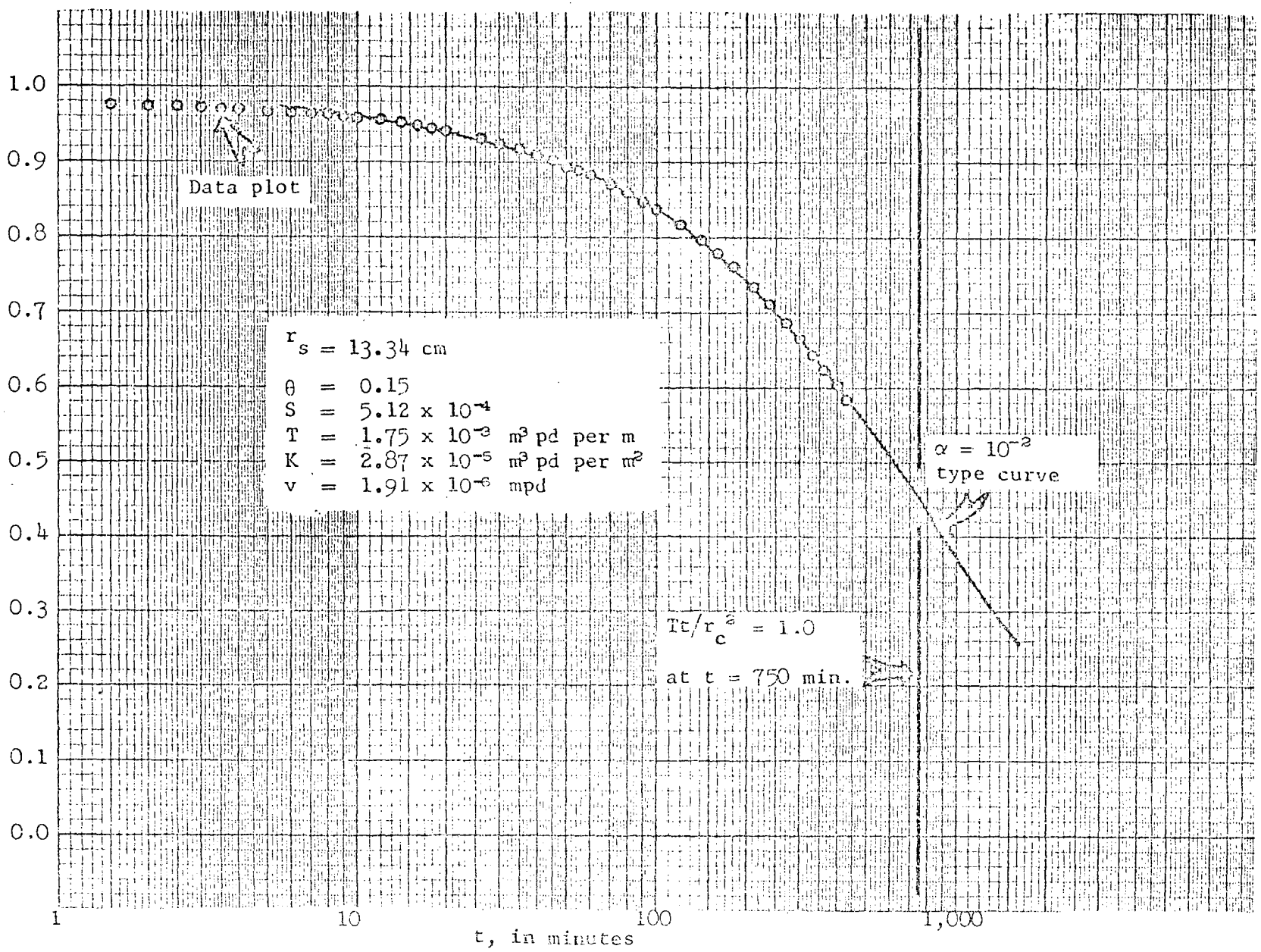

Figure 12.--Injection test of interval 2,212.5 to 2,273.5 m, hole UCe-17, Hot Creek Valley, Nevada.

Table 1.--Summary of hydraulic testing in hole UCe-17, Hot Creek Valley, Nevada

Zone	Interval tested (m below lsd)	Static water level 1/		Relative specific capacity 1/		Water swabbed		Specific conductance (micromhos per cm at 25°C)	Temperature		Packer 2/ bypass	Storage coefficient	Transmissivity		Hydraulic conductivity		Velocity		Rock type
		ft below lsd	m below lsd	gpm per ft of dd	m^3pd per m of dd	gal	m^3		°F	°C			gpd per ft	m^3pd per m	gpd per ft^2	m^3pd per m^2	ft pd	m pd	
1 3/	239.3- 279.0	475±	145±	High 4/	High 4/	400	1.5	350	65	18.3	No	--	--	--	--	--	--	--	Alluvium
		475±	145±	High 4/	High 4/						No								
1A 3,5/	539.6- 561.0	475±	145±	High 4/	High 4/	8,000	30	450	74	23.3	Yes	--	--	--	--	--	--	--	Do.
		475±	145±	0.01	0.179						No								
1 5/	957.0-1,018.0	882	268.9	.05	.894	10,000	38	430	98	36.7	Yes	--	e2.12 x10^{-2}	e2.63	e1.06	e4.31 x10^{-2}	e5.64 x10^{-3}	e1.72 x10^{-3}	Welded tuff
		--	--	--	--						--								
2	1,158.5-1,219.5	--	--	--	--	--	--	--	--	--	No	--	--	--	--	--	--	--	Do.
		--	--	--	--						No								
3 5/	1,223.2-1,284.1	--	--	-- 6/	-- 6/	6,000	23	360	93	33.9	Yes	--	--	--	--	--	--	--	Do.
		800(?)	244(?)	-- 6/	-- 6/						No								
4	1,387.7-1,428.7	--	--	e.001	e.018	3,000	11	1,200	82	27.8	No	--	e10.6	e1.31 x10^{-1}	e5.27 x10^{-3}	e2.15 x10^{-3}	e7.05 x10^{-4}	e2.15 x10^{-4}	Do.
		--	--	--	--						--								
5 5/	1,408.5-1,469.5	893	272.2	.23	4.11	5,000	19	900	95	35.0	Yes	--	e7.06 x10^{2}	e8.76	e3.53	e1.44 x10^{-1}	e4.72 x10^{-2}	e1.44 x10^{-2}	Do.
		--	--	--	--						--								
6	1,597.6-1,658.6	--	--	e.0003	e.0054	530	2.0	--	--	--	No	--	e2.12 x10^{-1}	e2.63 x10^{-3}	e1.06 x10^{-3}	e4.31 x10^{-5}	e2.83 x10^{-5}	e8.62 x10^{-6}	Do.
		--	--	--	--						--								
8	1,868.9-1,929.9	--	--	e.002	e.036	700	2.6	--	--	--	No	5.65x10^{-3}	2.12 x10^{-1}	2.63 x10^{-3}	1.06 x10^{-3}	4.31 x10^{-5}	9.42 x10^{-6}	2.87 x10^{-6}	Tuffaceous sediments
		--	--	--	--						--								
9	1,960.4-2,021.4	--	--	e.001	e.018	350	1.3	--	--	--	No	5.65x10^{-3}	6.82 x10^{-3}	8.47 x10^{-4}	3.41 x10^{-4}	1.39 x10^{-5}	3.04 x10^{-8}	9.27 x10^{-7}	Do.
		--	--	--	--						--								
10 6/	2,056.4-2,117.4	e1,150	e351	e.003	e.054	1,500	5.7	610	83	28.3	No	6.98x10^{-7}	5.29	6.57 x10^{-2}	2.65 x10^{-2}	1.08 x10^{-3}	2.36 x10^{-4}	7.2 x10^{-5}	Welded tuff
		--	--	e.002	e.036						--								
11	2,149.4-2,210.4	--	--	e.002	e.036	630	2.4	--	--	--	No	6.26x10^{-7}	1.93	2.39 x10^{-2}	9.60 x10^{-3}	3.92 x10^{-4}	1.29 x10^{-4}	3.92 x10^{-5}	Do.
		--	--	--	--						--								
12	2,212.5-2,273.5	--	--	e.0004	e.0072	--	--	--	--	--	No	5.12x10^{-4}	1.41 x10^{-1}	1.75 x10^{-3}	7.03 x10^{-4}	2.87 x10^{-5}	6.27 x10^{-6}	1.91 x10^{-6}	Do.
		--	--	--	--						--								

1/ Upper number from injection; lower number from recovery after swabbing.
2/ Upper-bypass around top packer; lower-bypass around bottom packer.
3/ Perforated casing and cement.
4/ High- recovery too rapid to measure.
5/ Sampled for chemical analysis.
6/ Cemented zone.

NOTE: Composite water level = 161.0 meters below lsd.

Explanation:

m - meters
lsd - land-surface datum
ft - feet
gpm - gallons per minute
dd - drawdown
m^3pd - cubic meters per day
gal - gallons
cm - centimeters
°C - degrees Centigrade
°F - degrees Fahrenheit
gpd - gallons per day
ft^2 - square feet
m^2 - square meters
ft pd - feet per day
mpd - meters per day
e - estimated

HOLE UCe-18

Hole UCe-18, at coordinates N. 1,396,833 ft and E. 635,840 ft, Nevada coordinate system, central zone, Nye County, Nevada, penetrated alluvium, lake beds and gypsum, rhyolite, and bedded tuff. The land-surface elevation at this site is 1,757 meters above mean sea level.

Hydrostatic head distribution

The greatest hydraulic potential was measured in the interval between 1,686 and 1,803 meters below land surface. The static water level in the interval was about 58 meters below land surface during testing. The hydraulic potential decreases both above and below this interval; however, the greatest potential is for upward movement of water in the borehole. The static water level in the interval from 1,874.7 to 1,986 meters was 64.0 meters below land surface. The static water level in the interval from 123.8 to 182.3 meters was about 100.6 meters below land surface.

Tracejector survey

The borehole was open to the formation from 1,463 to 1,931 meters during the static condition tracejector survey. The results of this survey indicate a potential for downward flow in this interval of rhyolite. Vertical flow in the borehole was downward at a rate of about 33 m^3pd with inflow at a depth of 1,530 meters and total outflow at a depth of 1,733 meters. There was no measurable flow in the borehole under static conditions either above 1,530 meters or below 1,733 meters.

A tracejector survey under dynamic conditions during pumping of water at a rate of 900 m^3pd indicates that most of the pumped water came from a depth of 1,733 meters and from an interval in the alluvium from 124 to 182 meters (fig. 13). These two major contributing zones did not have the greatest hydraulic potential, but they were two of the most permeable zones.

Specific capacity

The well was pumped for a short time before the tracejector survey was made. The pump intake was at 149 meters below land surface; the discharge was 916 m^3pd; and the drawdown was 16.51 meters after about 9 hours of pumping. Therefore, the specific capacity during this test was 55.5 m^3pd per m of drawdown.

Hydraulic characteristics

Due to methods of drilling and hydraulic testing used in UCe-18, only the data from the injection test of interval 1,237.8 to 1,277.4 meters could be used for the type of analysis employed in this report. That analysis is presented in figure 14.

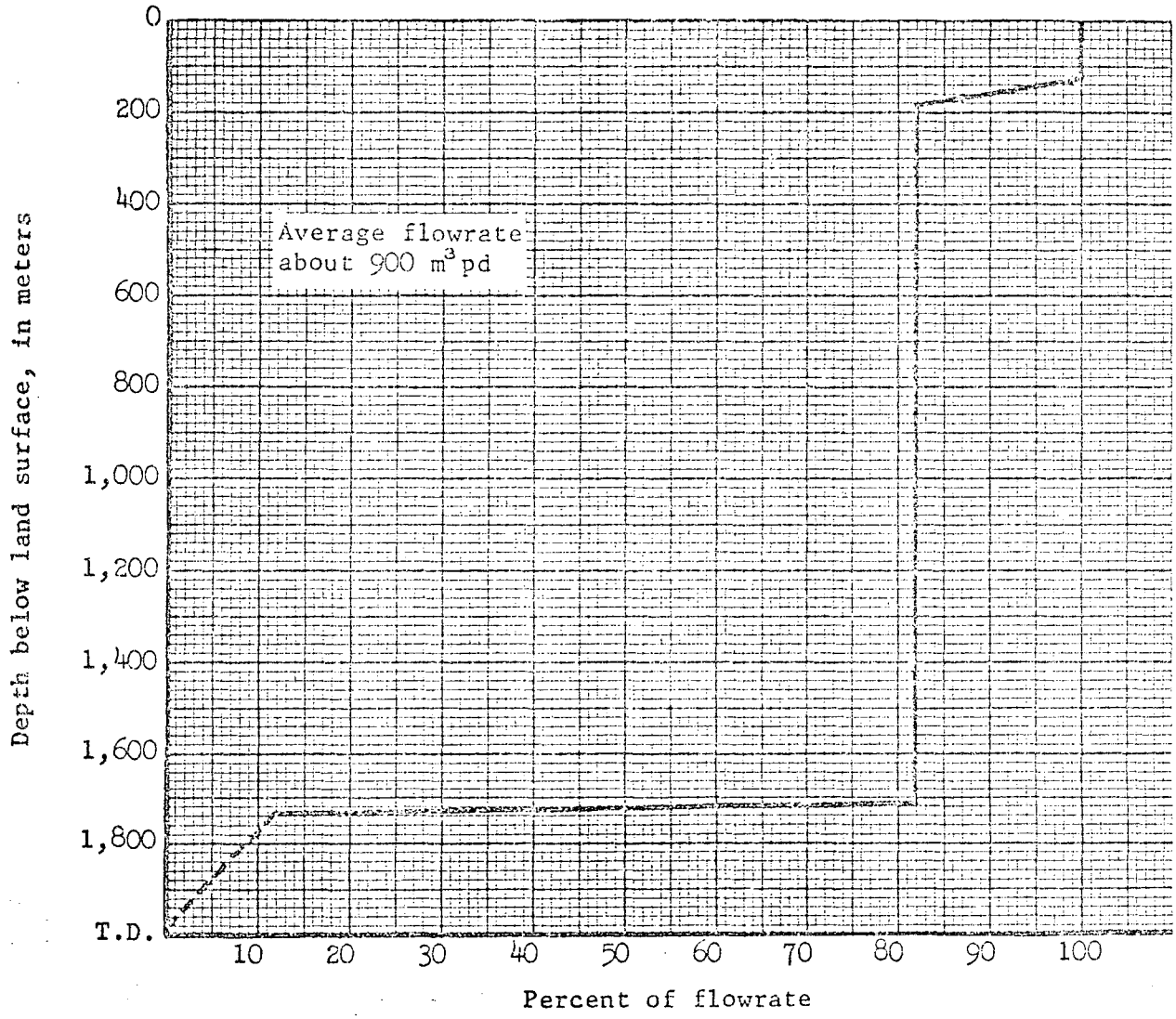

Figure 13.--Tracejector survey of hole UCe-18, Hot Creek Valley, Nevada, while pumping.

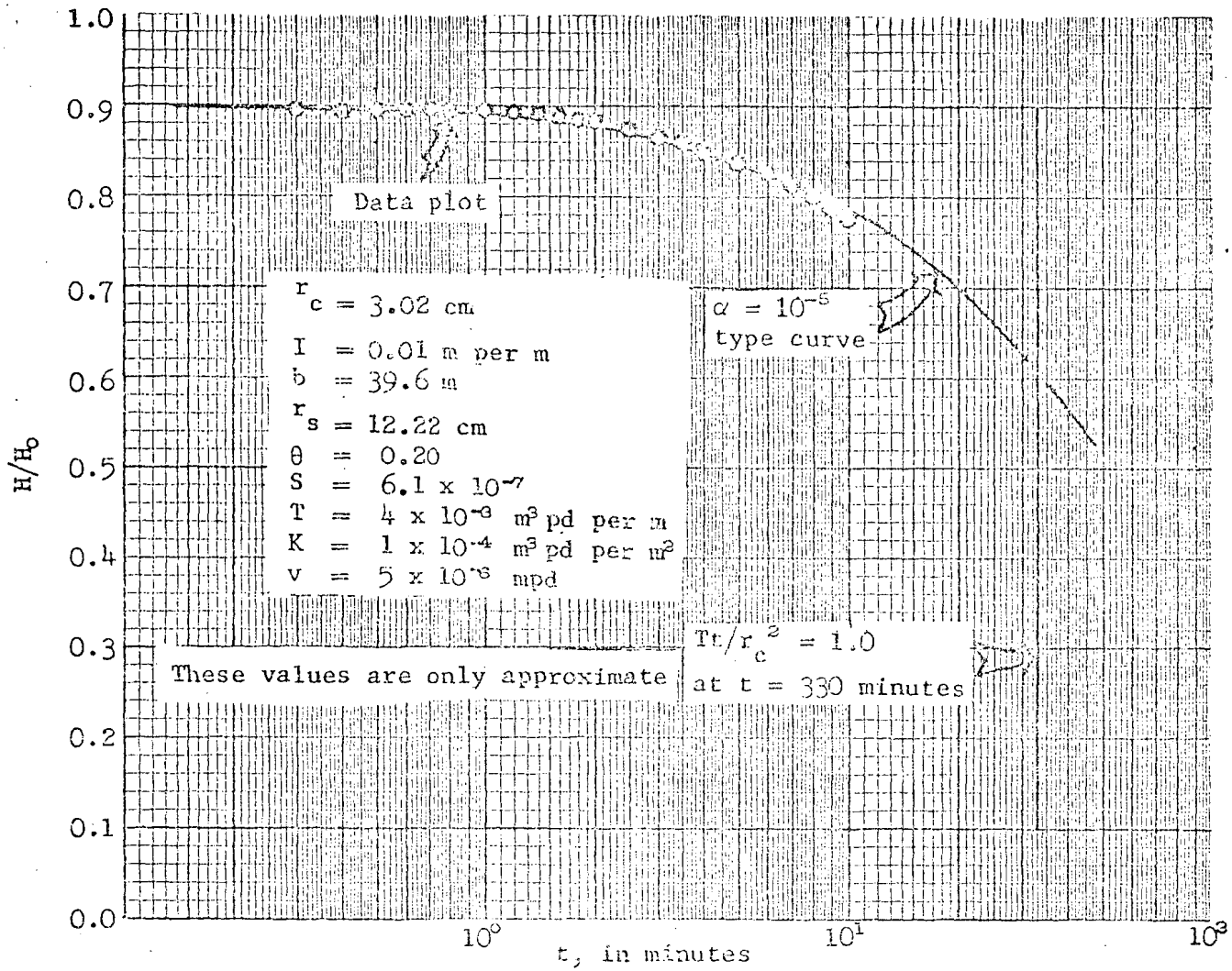

Figure 14.--Injection test of interval 1,237.8 to 1,277.4 m, hole UCe-20, Hot Creek Valley, Nevada.

Table 2.--Summary of hydraulic testing in hole UCe-18, Hot Creek Valley, Nevada

Zone	Interval tested (m below lsd)	Static water level 1/		Relative specific capacity 1/		Water swabbed		Specific conductance (micromhos per cm at 25°C)	Temperature		Packer bypass 2/	Storage coefficient	Transmissivity		Hydraulic conductivity		Velocity		Rock type
		ft below lsd	m below lsd	gpm per ft of dd	m^3pd per m of dd	gal	m^3		°F	°C			gpd per ft	m^3pd per m	gpd per ft^2	m^3pd per m^2	ft pd	m pd	
11 3/4/	123.8- 182.3	330	100.6	High 5/	High 5/	14,500	55	1,200	92	33.3	No	--	--	--	--	--	--	--	Alluvium
		330	100.6	High 5/	High 5/						Lost								
10 2/	1,237.8-1,277.4	--	--	Low 5/	Low 5/	1,750	6.6	--	--	--	Yes	e6.1x10^{-7}	e3.2 x10^{-1}	e4 x10^{-3}	e2.45 x10^{-3}	e1 x10^{-4}	e1.64 x10^{-6}	e5 x10^{-8}	Do.
		--	--	--	--						Lost								
9 2/4/	1,388.7-1,447.3	--	--	--	--	28,000	106	1,400(?)	112(?)	44.5(?)	Yes	--	--	--	--	--	--	--	Rhyolite
		--	--	--	--						Lost								
12 4/	1,461.9-1,522.9	--	--	--	--	22,000	83	1,800	99	37.2	Lost	--	--	--	--	--	--	--	Do.
		--	--	--	--						No								
5 4/	1,530.5-1,579.3	--	--	--	--	17,500	66	3,000	107	41.7	Slight	--	--	--	--	--	--	--	Do.
		--	--	High 5/	High 5/						No								
8 2/	1,615.9-1,649.4	--	--	-- 6/	-- 6/	27,000	102	3,000	130	54.4	Slight	--	--	--	--	--	--	--	Do.
		194.6	59.3	-- 6/	-- 6/						No								
7 2/	1,686.0-1,719.5	--	--	--	--	20,500	78	3,000	120	48.9	Slight	--	--	--	--	--	--	--	Do.
		e190	e58	0.02	0.36						No								
4 2/	1,717.7-1,766.5	e210	e64	High 5/	High 5/	16,000	61	3,000	118	47.8	No	--	--	--	--	--	--	--	Do.
		e210	e64	High 5/	High 5/						No								
6 2/	1,769.5-1,803.0	--	--	--	--	28,500	108	2,900	129	53.9	No	--	--	--	--	--	--	--	Do.
		e190	e58	.2	3.6						No								
3 2/	1,804.9-1,853.7	--	--	--	--	9,000	34	3,000	105	40.6	No	--	--	--	--	--	--	--	Do.
		--	--	e.001	e.016						No								
2 2/	1,874.7-1,986.0	--	--	-- 6/	-- 6/	18,000	68	2,950	118	47.8	--	--	--	--	--	--	--	--	Rhyolite and bedded tuff
		210	64.0	-- 6/	-- 6/						No								
1	1,948.2-1,986.0	--	--	-- 6/	-- 6/	1,400	5.3	--	--	--	--	--	--	--	--	--	--	--	Do.
		--	--	-- 6/	-- 6/						No								

1/ Upper number from injection; lower number from recovery after swabbing.
2/ Upper-bypass around top packer; lower-bypass around bottom packer; lost-recorder lost in borehole.
3/ Perforated casing and cement.
4/ Sampled for chemical analysis.
5/ High-recovery too rapid to measure; low-recovery too small to measure accurately.
6/ Cemented zone.

NOTE: Composite water level = 59.8 meters below lsd.

Explanation:

m - meters
lsd - land-surface datum
ft - feet
gpm - gallons per minute
dd - drawdown
m^3pd - cubic meters per day
gal - gallons
cm - centimeters
°C - degrees Centigrade
°F - degrees Fahrenheit
gpd - gallons per day
ft^2 - square feet
m^2 - square meters
ft pd - feet per day
mpd - meters per day
e - estimated

HOLE UCe-20

Hole UCe-20, at coordinates N. 1,399,868.46 ft and E. 628,092.75 ft, Nevada coordinate system, central zone, Nye County, Nevada, penetrated alluvium, zeolitized welded tuff, tuffaceous conglomerate, and partly to densely welded tuff. The land-surface elevation at this site is 1,755.8 meters above mean sea level.

Hydrostatic head distribution

The greatest hydraulic potential was measured in the interval from 1,652.4 to 1,670.7 meters below land surface. The static water level in this interval was 65.5 meters below land surface during testing. The hydraulic potential decreases both above and below this interval. The static water level in the interval 213.4 to 219.5 meters was about 103.7 meters below land surface. The static water level in the interval 1,679.9 to 1,829.3 meters was 84.5 meters below land surface.

Tracejector survey

A tracejector survey run under static conditions indicated no measurable movement of water in the borehole. This lack of movement under static conditions indicates very little hydrostatic head difference in the vertical section, insufficient hydraulic conductivity for measurable exchange of water from one zone to another, or both.

A tracejector survey under dynamic conditions during jetting of water at a rate of about 820 m^3pd indicates that most of the jetted water came from a depth of about 1,658 meters (fig. 15). This depth is within the interval 1,652.4 to 1,670.7 meters which had the greatest measured hydrostatic potential and which was one of the most permeable zones.

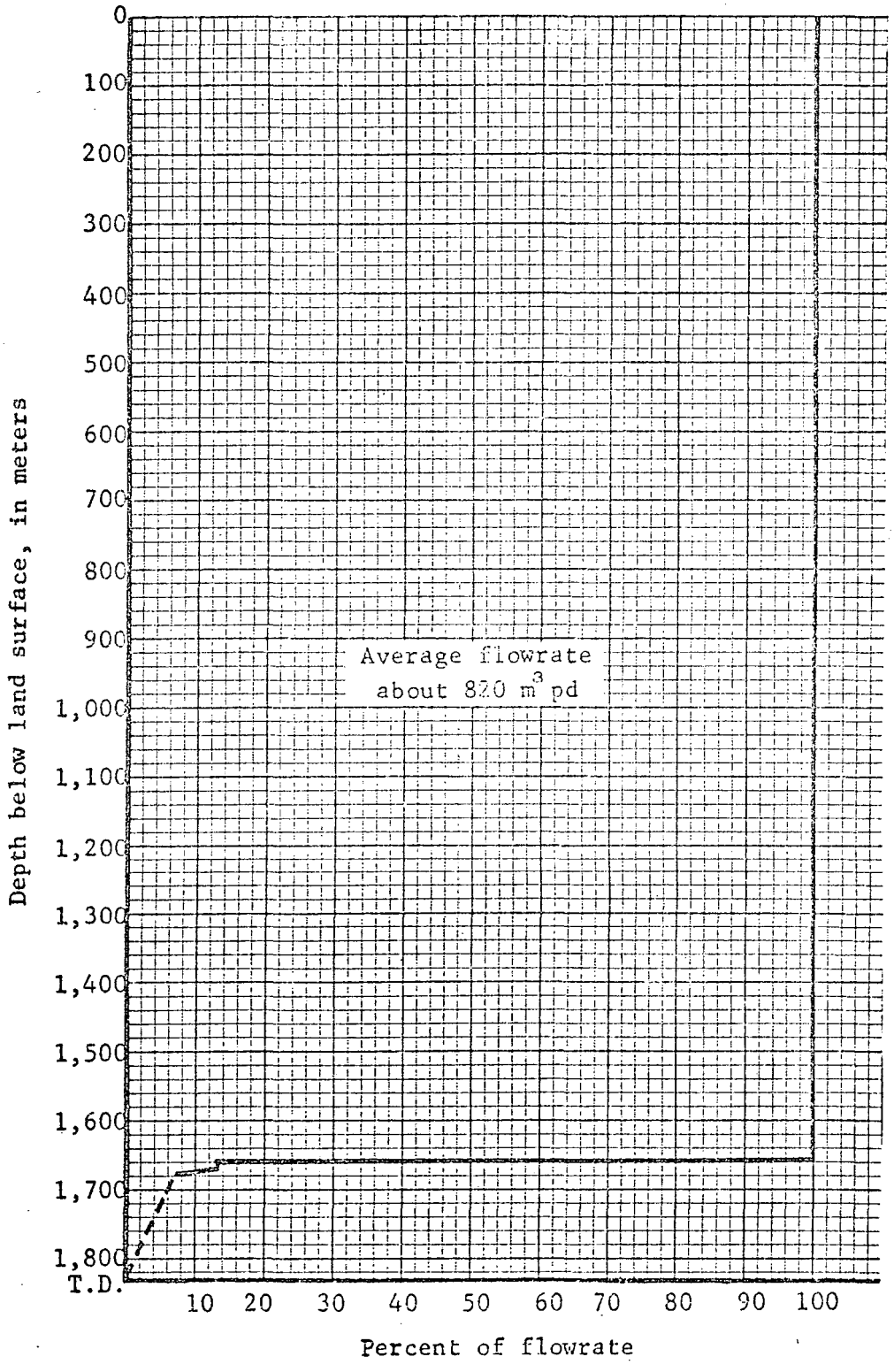

Figure 15.--Tracejector survey of hole UCe-20, Hot Creek Valley, Nevada, while jetting.

Hydraulic characteristics

The analyses of data from injection into individual intervals in hole UCe-20 are presented in figures 16-29. The parameter r_c = 3.02 cm is constant, and the variable parameters are shown on the figures.

Inflow to an underground chamber

This is a theoretical consideration and analysis of time-dependent decay characteristics of water inflow to an underground chamber. The leaky artesian, constant-drawdown formula derived by Hantush (1959) and modified by Walton (1962) as a type-curve solution can be used to analyze the deep-well test data in terms of inflow to an underground chamber if certain basic assumptions of physical conditions are made. These assumptions are: 1) that partial penetration in the center of an aquifer can be treated as a leaky-aquifer problem with leakage from above and below; 2) that aquitards above and below can be treated as a single aquitard above, with the recharge reservoir also above; 3) that initial heads in this small aquifer-aquitard system are about the same; 4) that inflow effects at the ends of the chamber can be approximated by adding compensating length to the cylinder; 5) that underreaming is sufficiently rapid to simulate instant drawdown; and 6) that construction includes a sealed sump that accepts all inflow to the chamber thus simulating constant drawdown at the base of the chamber.

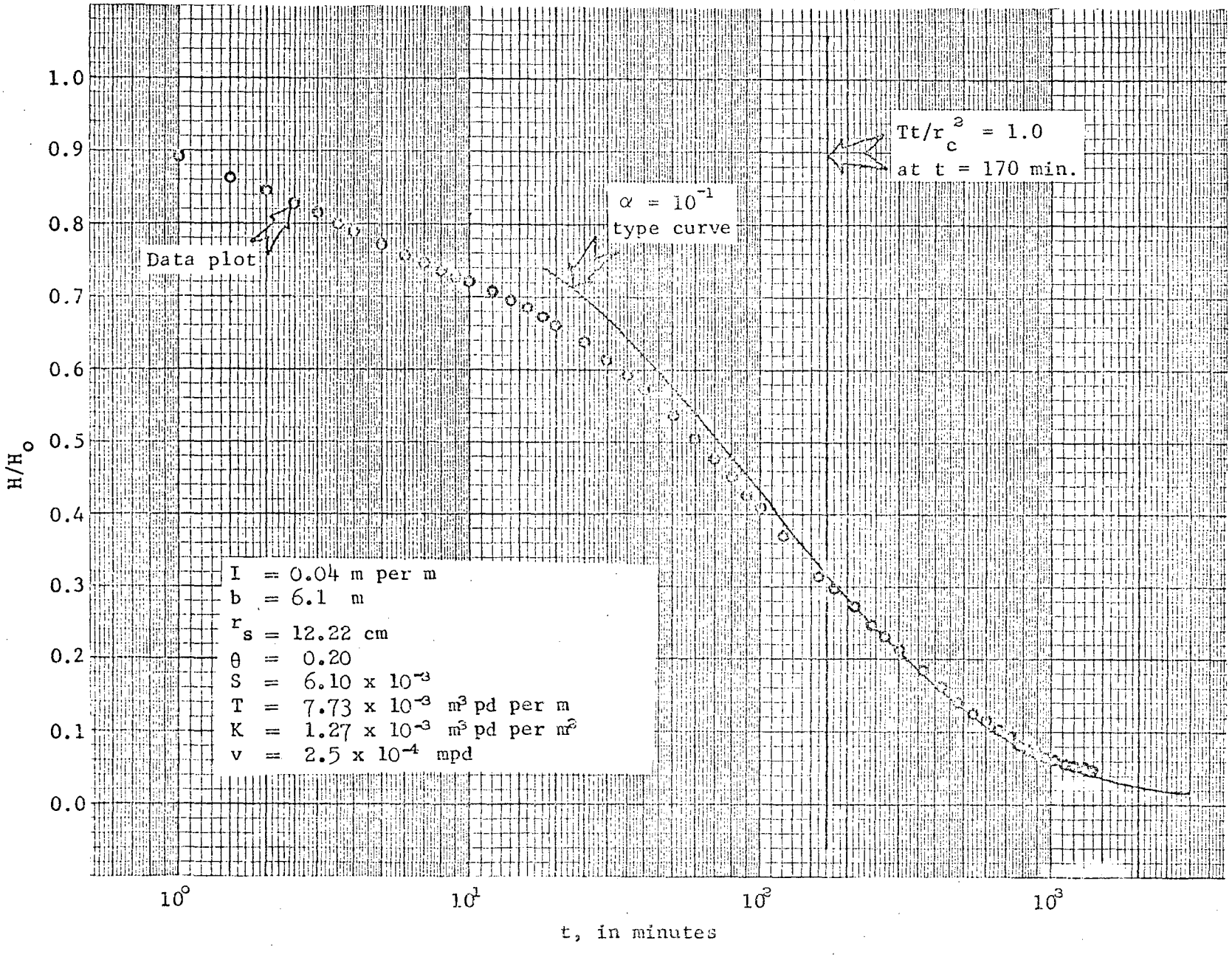

Figure 16--Injection test of interval 213.4 to 219.5 m, hole UCe-20, Hot Creek Valley, Nevada.

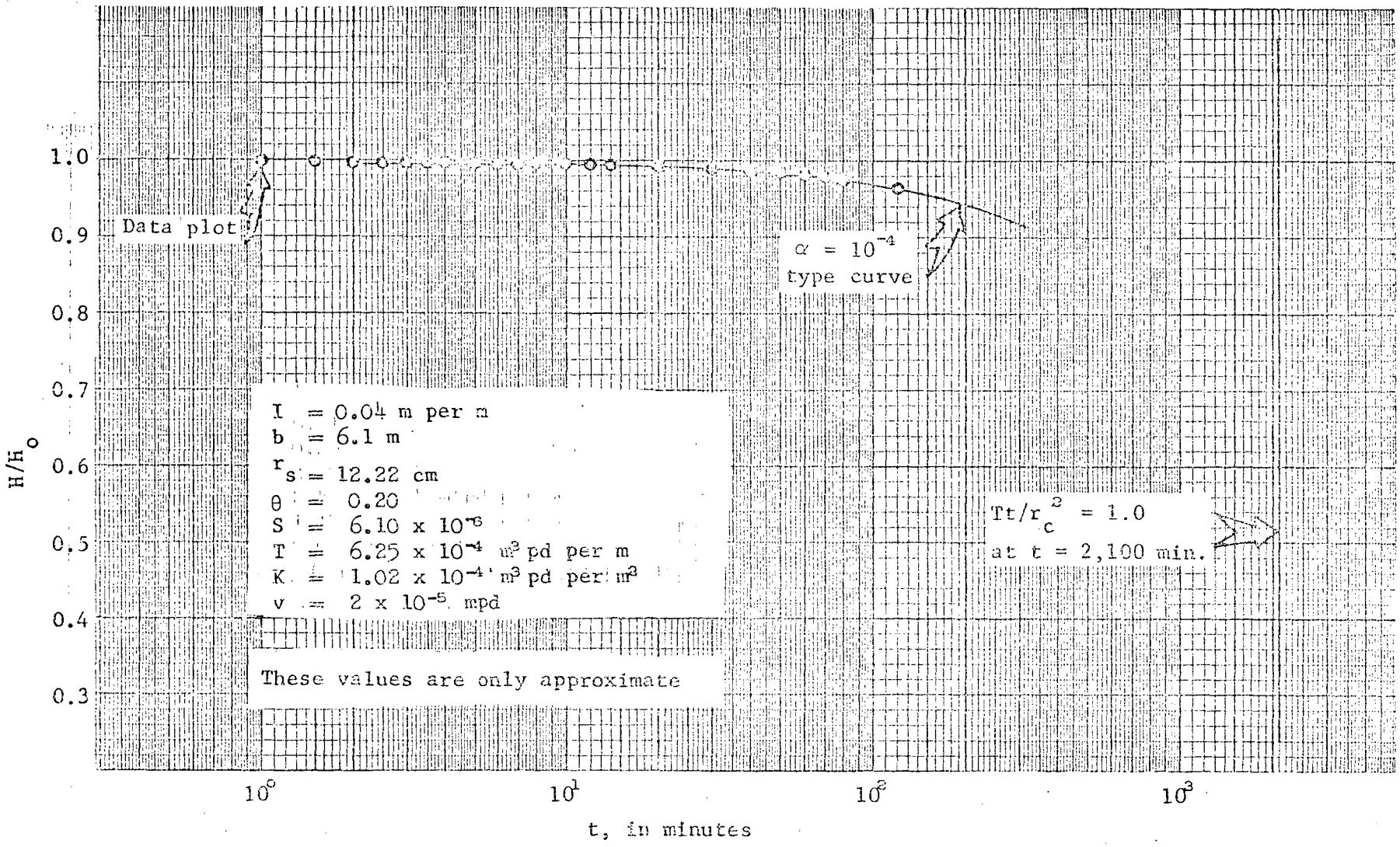

Figure 17.--Injection test of interval 670.7 to 676.8 m, hole UCe-20, Hot Creek Valley, Nevada.

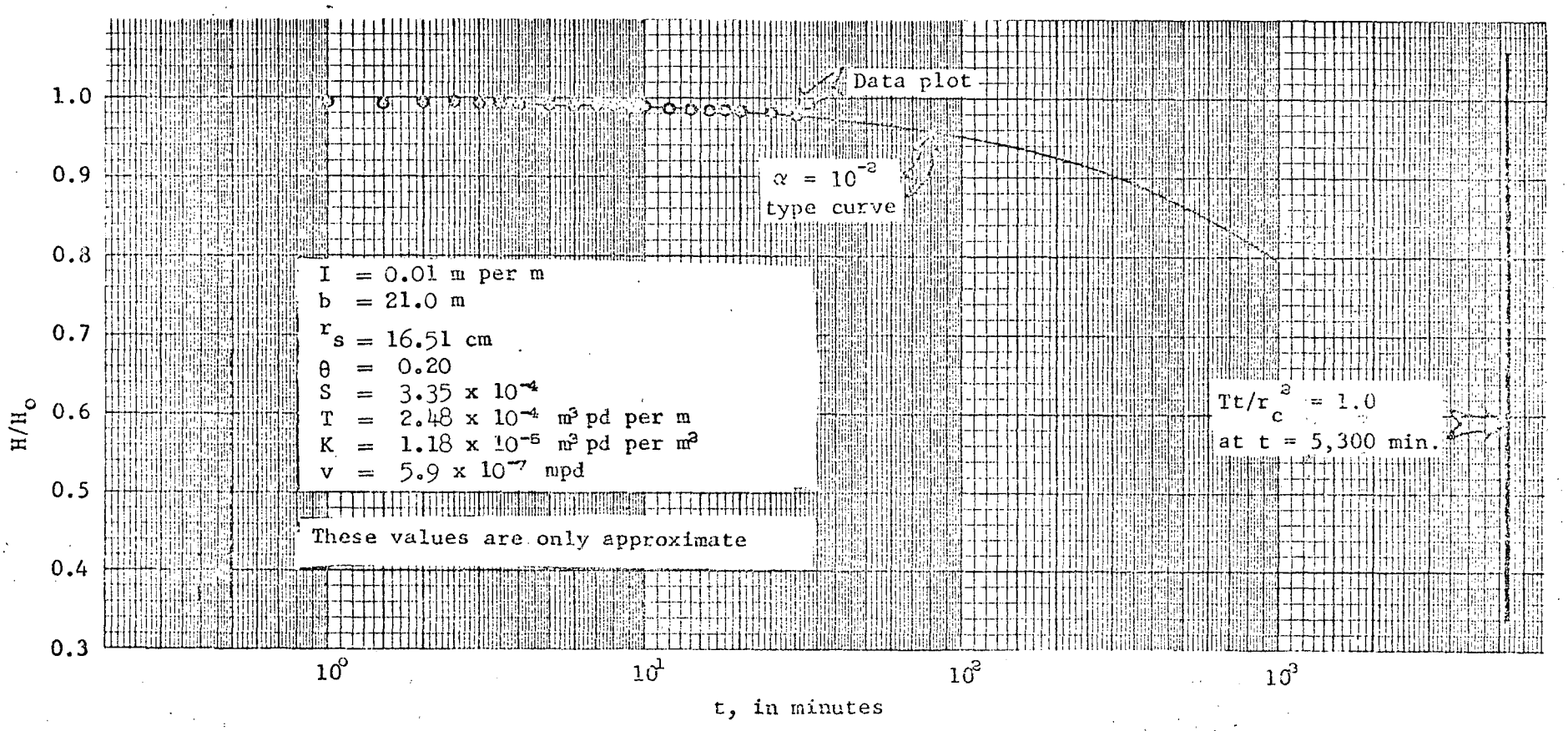

Figure 18.--Injection test of interval 1,481.4 to 1,502.4 m, hole UCe-20, Hot Creek Valley, Nevada.

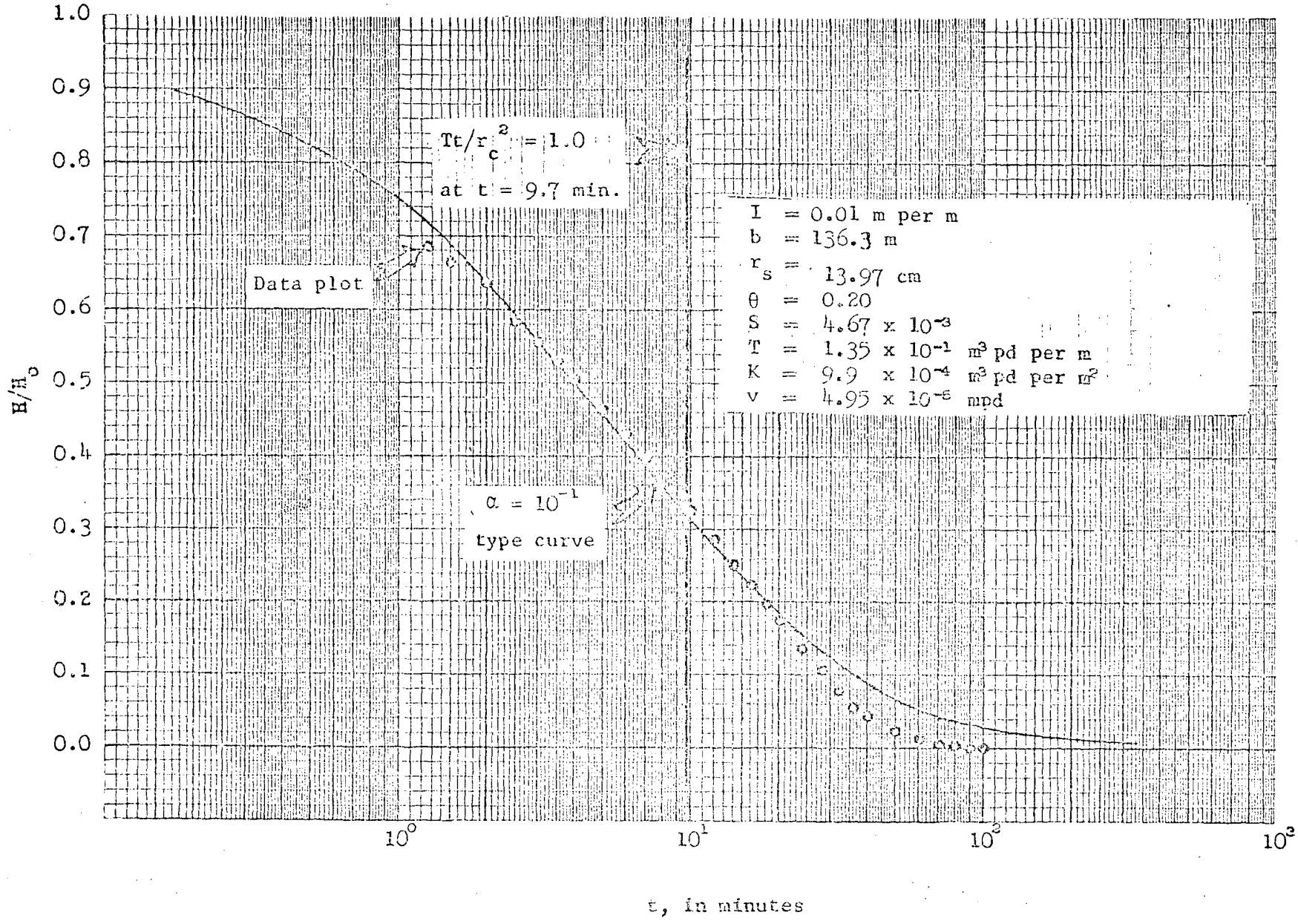

Figure 19.--Injection test of interval 1,481.4 to 1,617.7 m, hole UCe-20, Hot Creek Valley, Nevada.

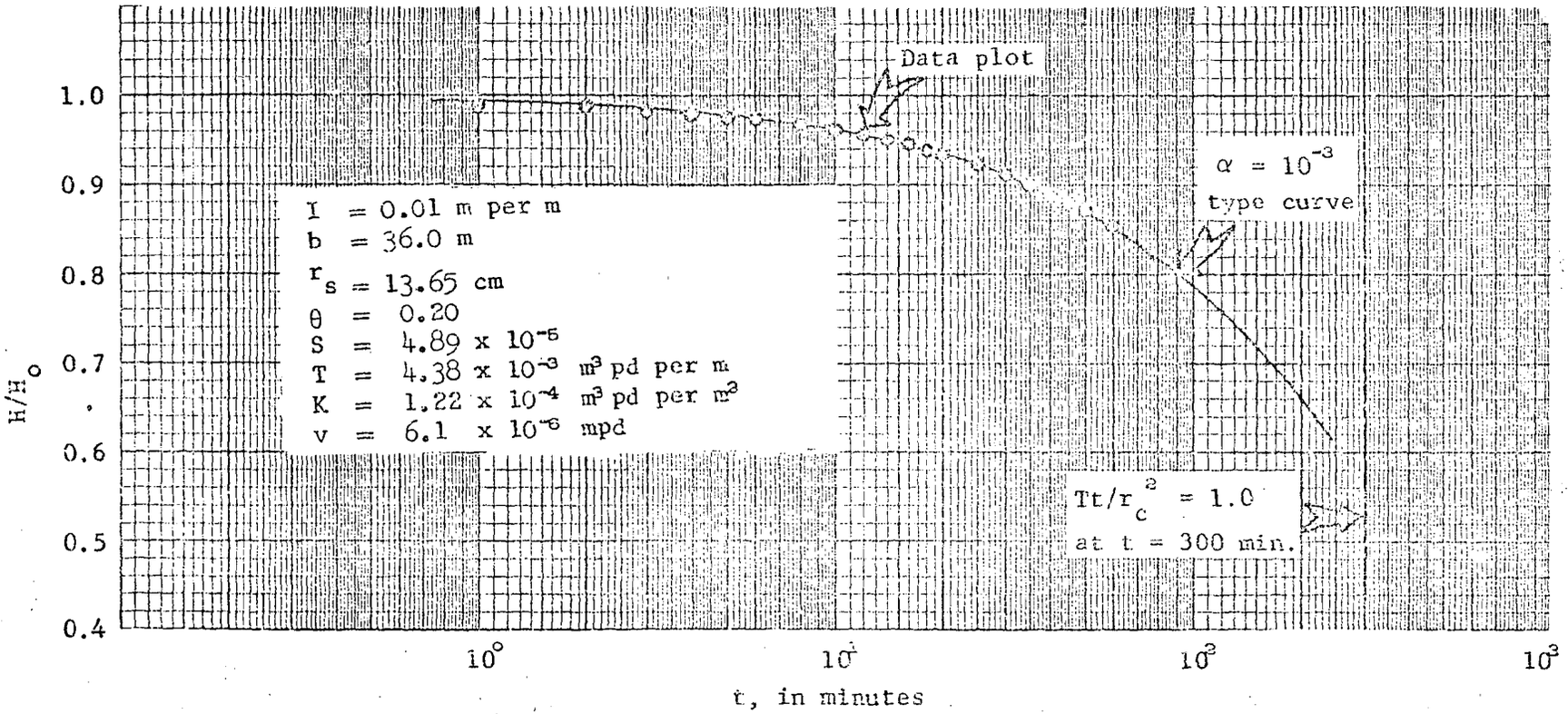

Figure 20.--Injection test of interval 1,502.4 to 1,538.4 m, hole UCe-20, Hot Creek Valley, Nevada.

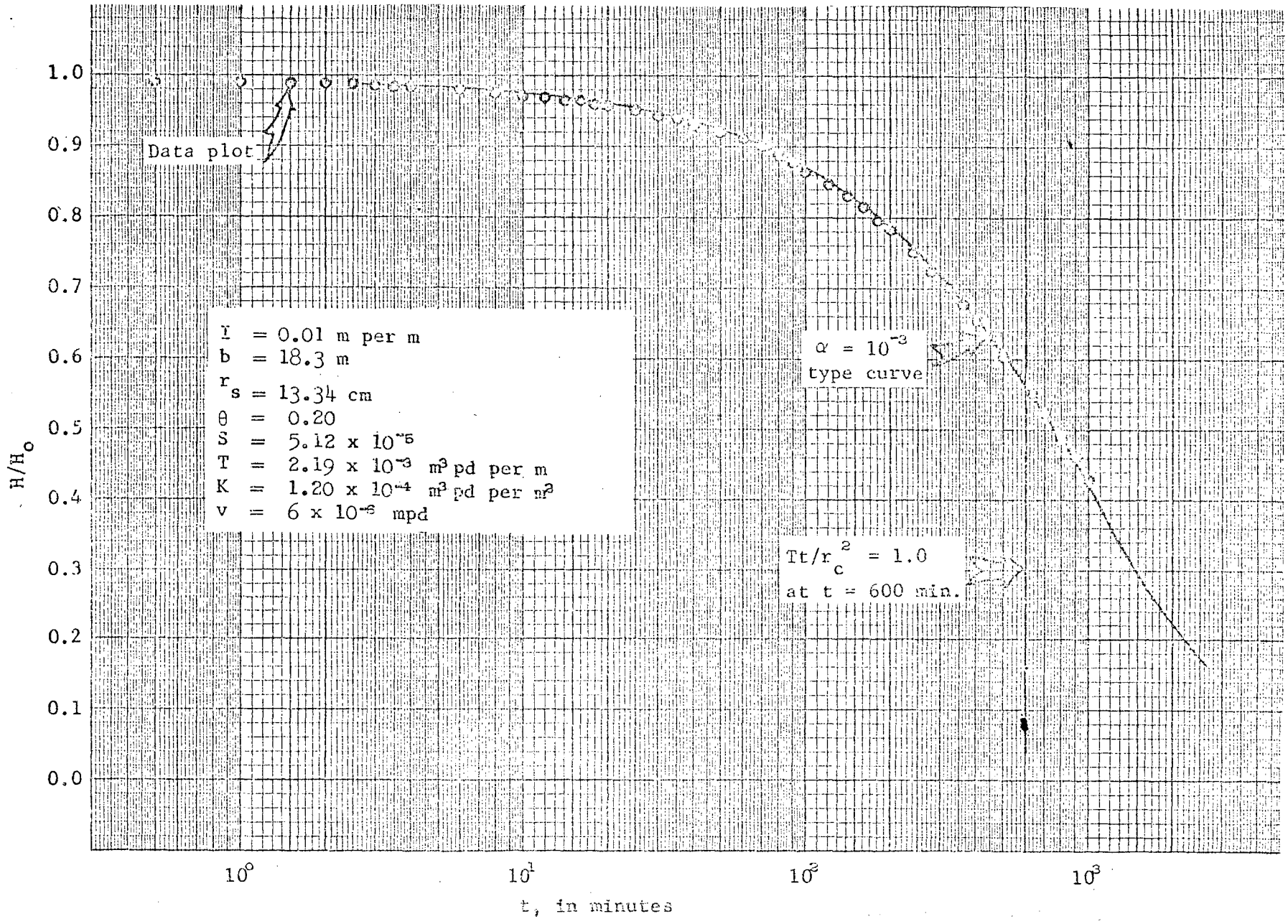

Figure 21.--Injection test of interval 1,521.3 to 1,539.6 m, hole UCe-20, Hot Creek Valley, Nevada.

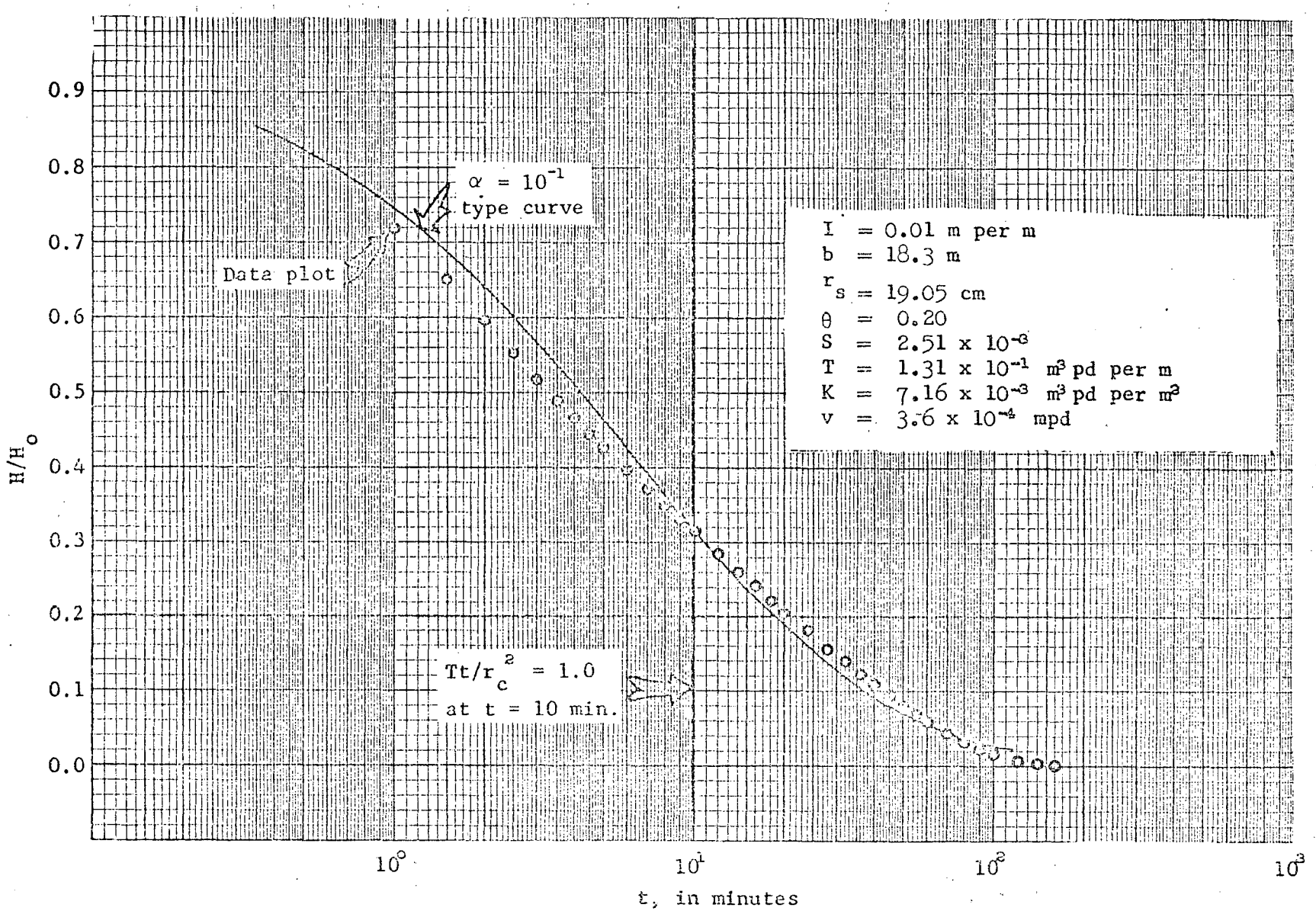

Figure 22.--Injection test of interval 1,539.6 to 1,557.9 m, hole UCe-20, Hot Creek Valley, Nevada.

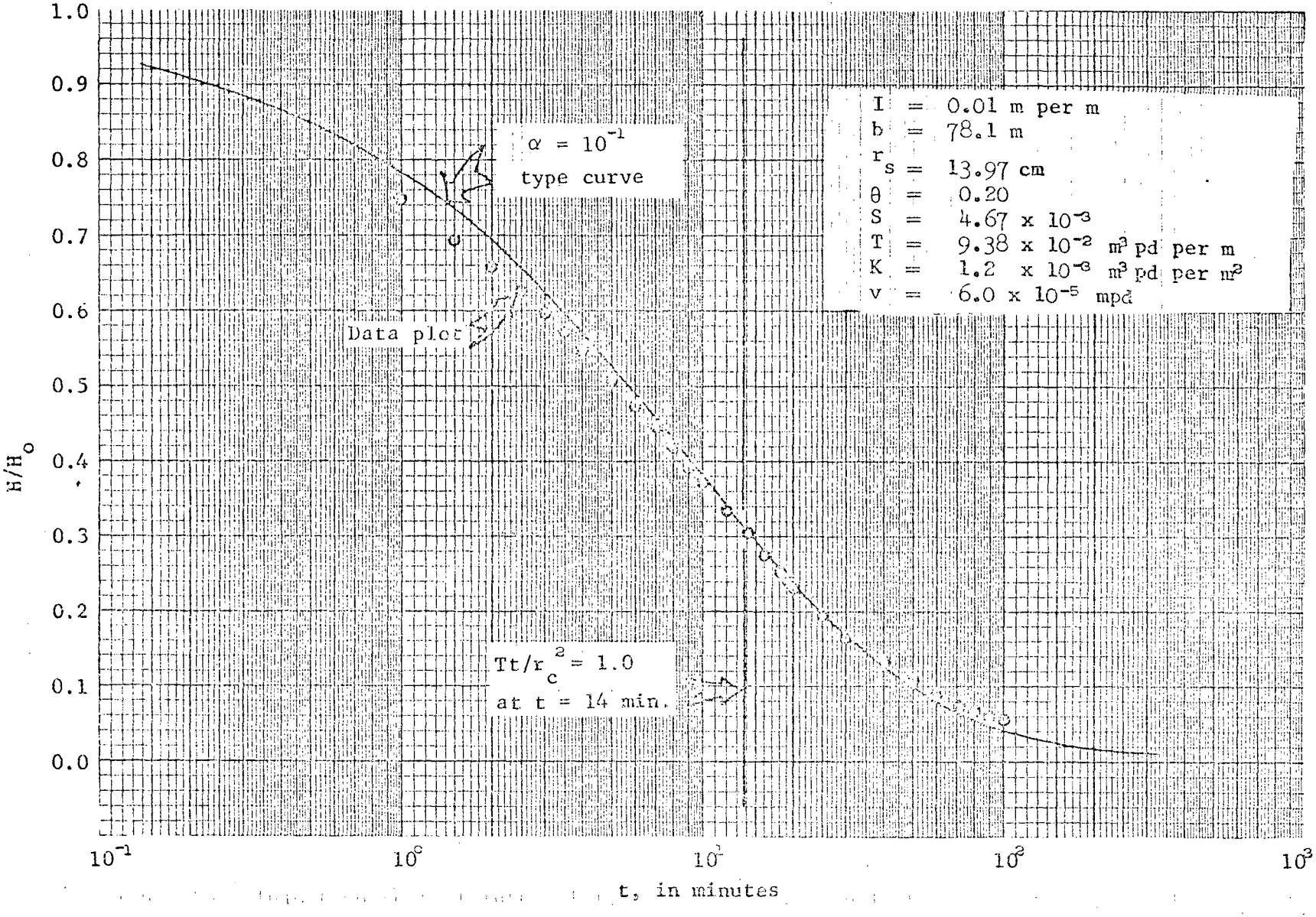

Figure 23.--Injection test of interval 1,539.6 to 1,617.7 m, hole UCe-20, Hot Creek Valley, Nevada.

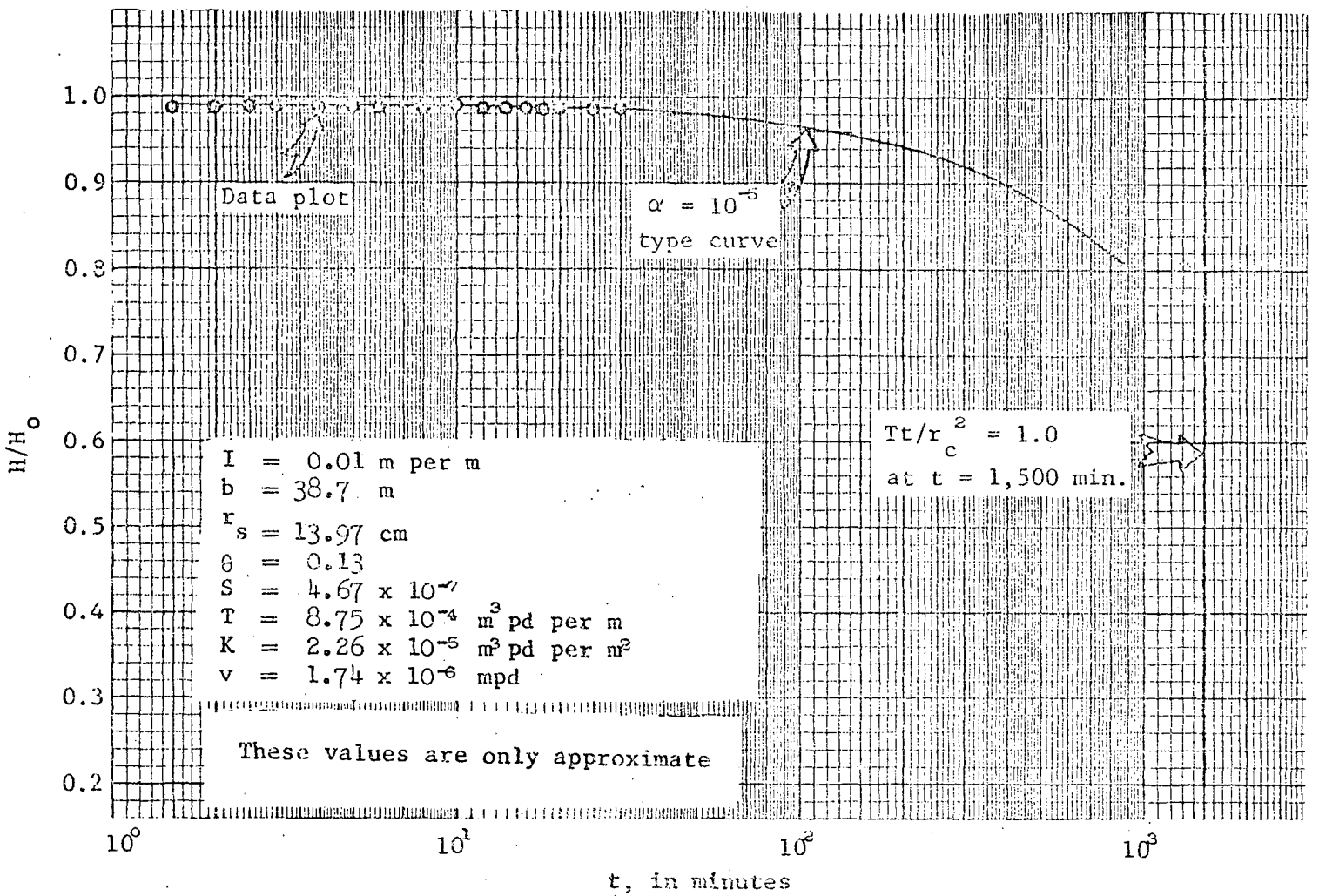

Figure 24.--Injection test of interval 1,579 to 1,617.7 m, hole UCe-20, Hot Creek Valley, Nevada.

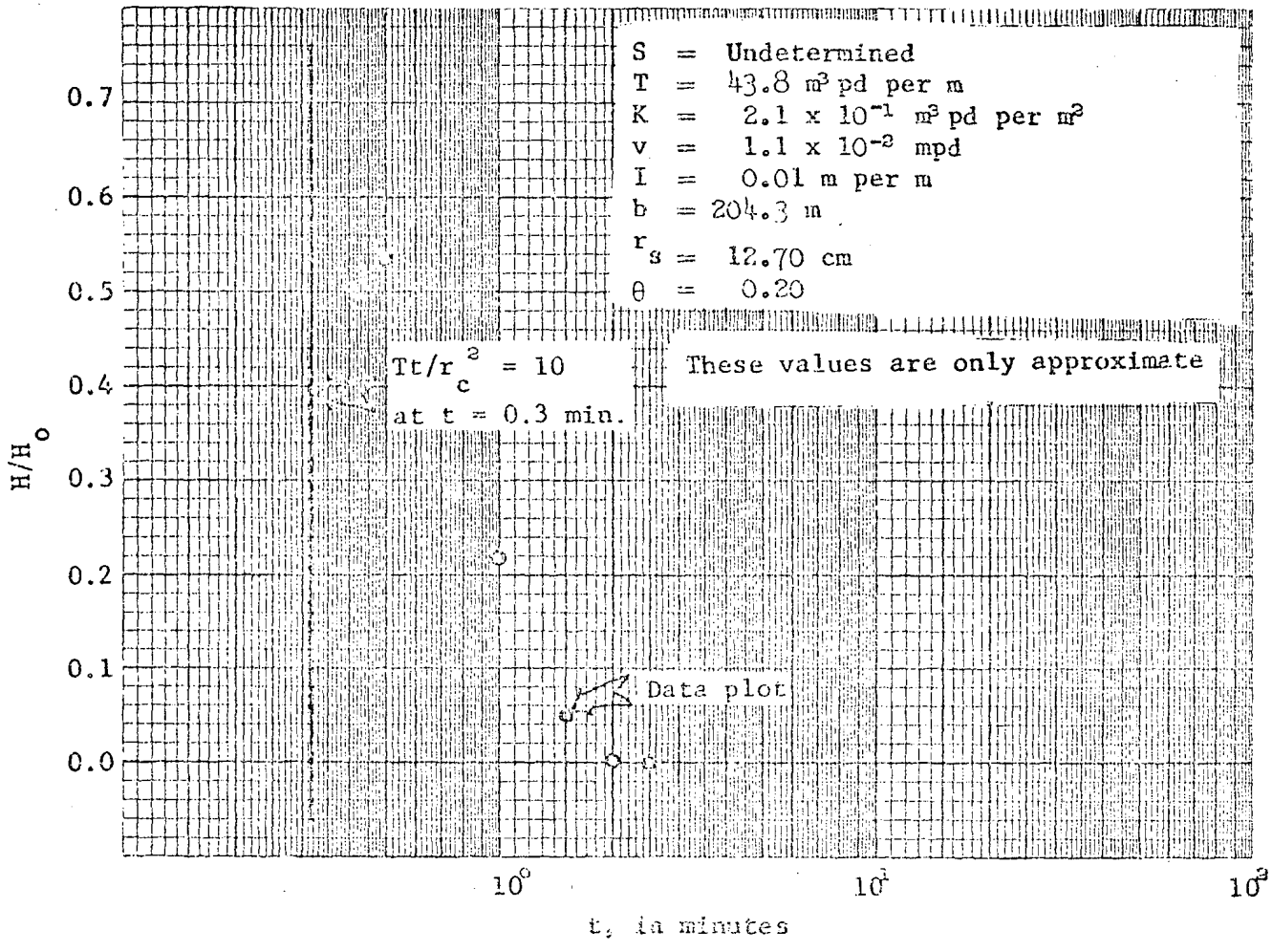

Figure 25.--Injection test of interval 1,625 to 1,829.3 m, hole UCe-20, Hot Creek Valley, Nevada.

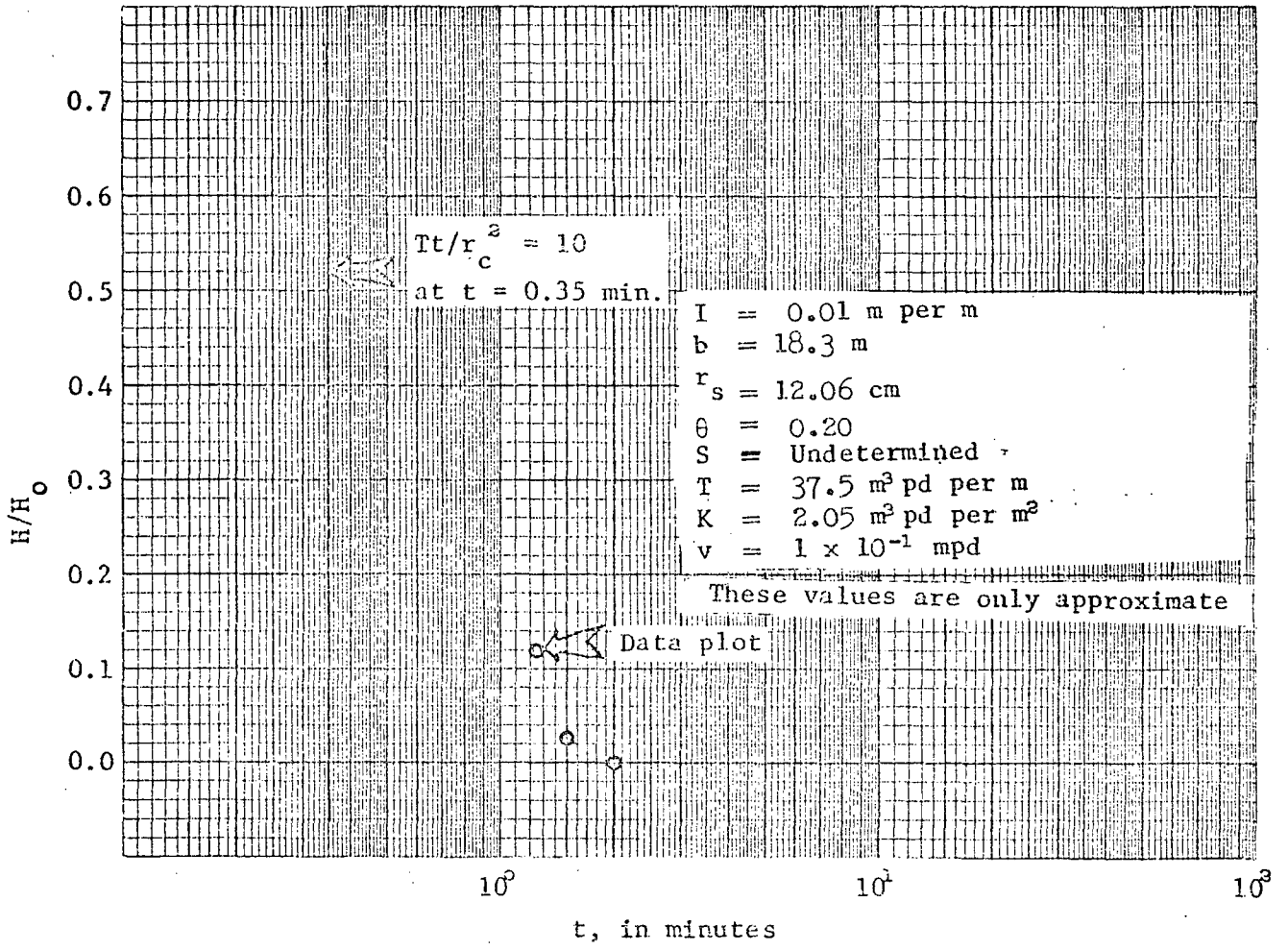

Figure 26.--Injection test of interval 1,652.4 to 1,670.7 m, hole UCe-20, Hot Creek Valley, Nevada.

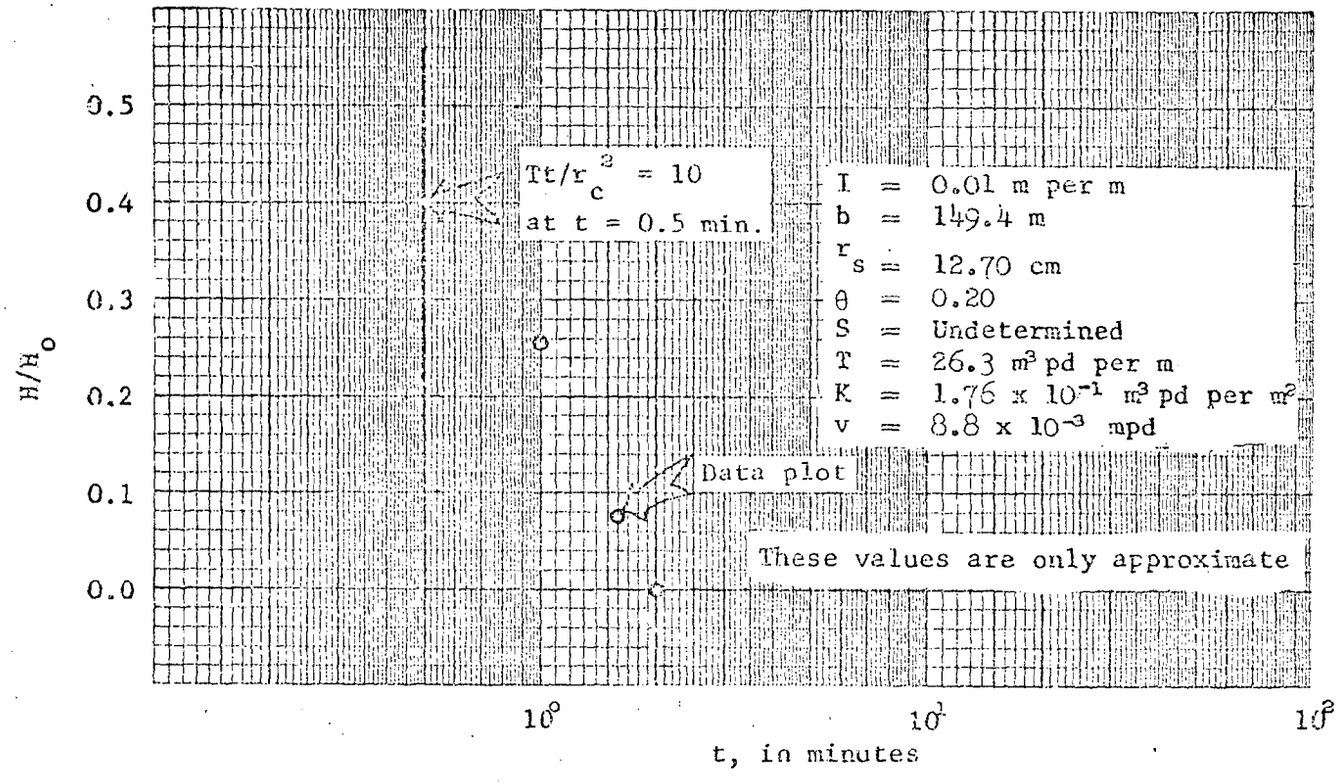

Figure 27.--Injection test of interval 1,680 to 1,829.3 m, hole UCe-20, Hot Creek Valley, Nevada.

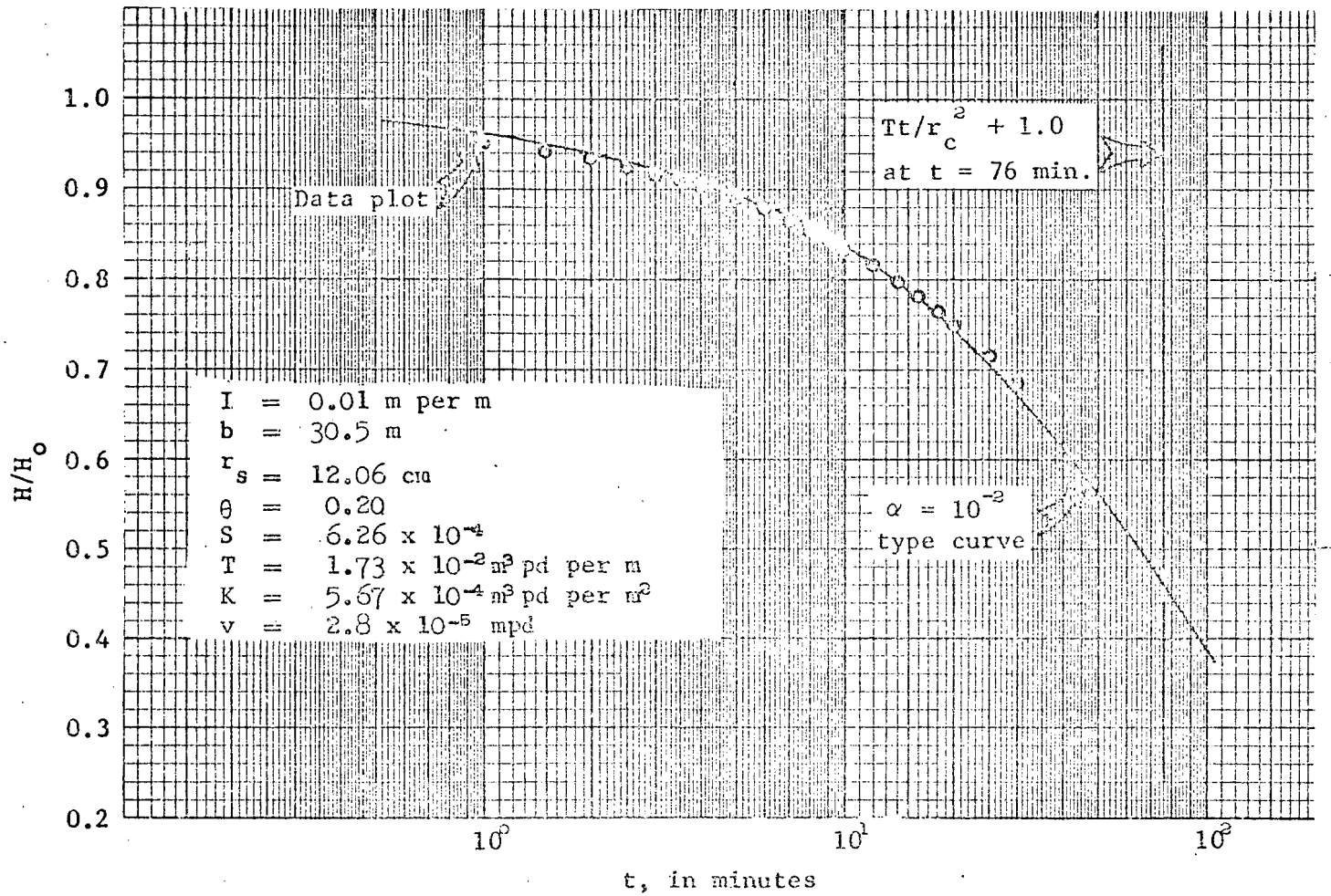

Figure 28.--Injection test of interval 1,798.8 to 1,829.3 m, hole UCe-20, Hot Creek Valley, Nevada.

The formula that describes leaky artesian constant-drawdown variable discharge conditions as presented by Walton (1962) is:

$$s_w = 229Q/[G(\lambda, r_w/B)T]$$

$$\lambda = 9.29\times10^{-5}Tt/r_w^2S$$

$$r_w/B = r_w/\sqrt{T/(P'/m')}$$

where:

$$G(\lambda, r_w/B) = (r_w/B)[K_1(r_w/B)/K_0(r_w/B)] + (4/\pi^2)\exp[-\lambda(r_w/B)^2] \int_0^\infty \frac{u\exp(-\lambda u^2)}{J_0^2(u) + Y_0^2(u)} \cdot \frac{du}{u^2 + (r_w/B)^2}$$

$u = r_w\sqrt{1/\exp(i\pi)B^2}$

T = coefficient of transmissivity, in gpd/ft

S = coefficient of storage, fraction

Q = discharge, in gpm

r_w = nominal radius of pumped well, in ft

s_w = drawdown in pumped well, in ft

t = time after discharge started, in min

P' = coefficient of vertical hydraulic conductivity of confining bed, in gpd/sq ft

m' = thickness of confining bed through which leakage occurs, in ft

$K_1(r_w/B)$ = first-order modified Bessel function of the second kind

$K_0(r_w/B)$ = zero-order modified Bessel function of the second kind

$J_0(u)$ = zero-order Bessel function of the first kind

$Y_0(u)$ = zero-order Bessel function of the second kind

For purposes of analysis, the cylindrical chamber in UCe-20 is assumed to be from 1,524.4 to 1,533.5 meters below land surface (9.1 meters long) and to have a diameter of 3.66 meters. The solution to the well function for leaky artesian aquifers and constant drawdown, G $(\lambda, r_w/B)$ has been worked out only for the practical ranges of λ and r_w/B that are used frequently. Unfortunately, the problem of inflow to chambers is concerned with unique characteristics of low transmissivity and low hydraulic conductivity; therefore, the solutions of many inflow problems lie outside the normal range of the type curves and approximations must be made. Such is the case in UCe-20, and several approximations were made by varying transmissivity and the vertical component of hydraulic conductivity both jointly and independently. It is assumed because of the position of terms in various equations that varying the hydraulic conductivity is less critical than varying the transmissivity; therefore, the actual inflow-decay curve probably lies closer to the adjusted-conductivity, inflow-decay curve than it does to the adjusted-transmissivity, inflow-decay curve (fig. 29). The actual inflow-decay curve might be approximated by the dashed "theoretical" curve in figure 29. An approximation of inflow based on relative specific capacity prepared by W. E. Hale indicates an inflow of less than 100 m^3pd, but this probably is close to initial inflow and does not indicate decay characteristics.

Best approximations using the leaky artesian, constant-drawdown analysis indicate that inflow to the theoretical chamber would be between 4.9 and 450 m^3pd after 10^5 minutes (about 70 days) and that inflow probably would be about 14 m^3pd after 10^5 minutes.

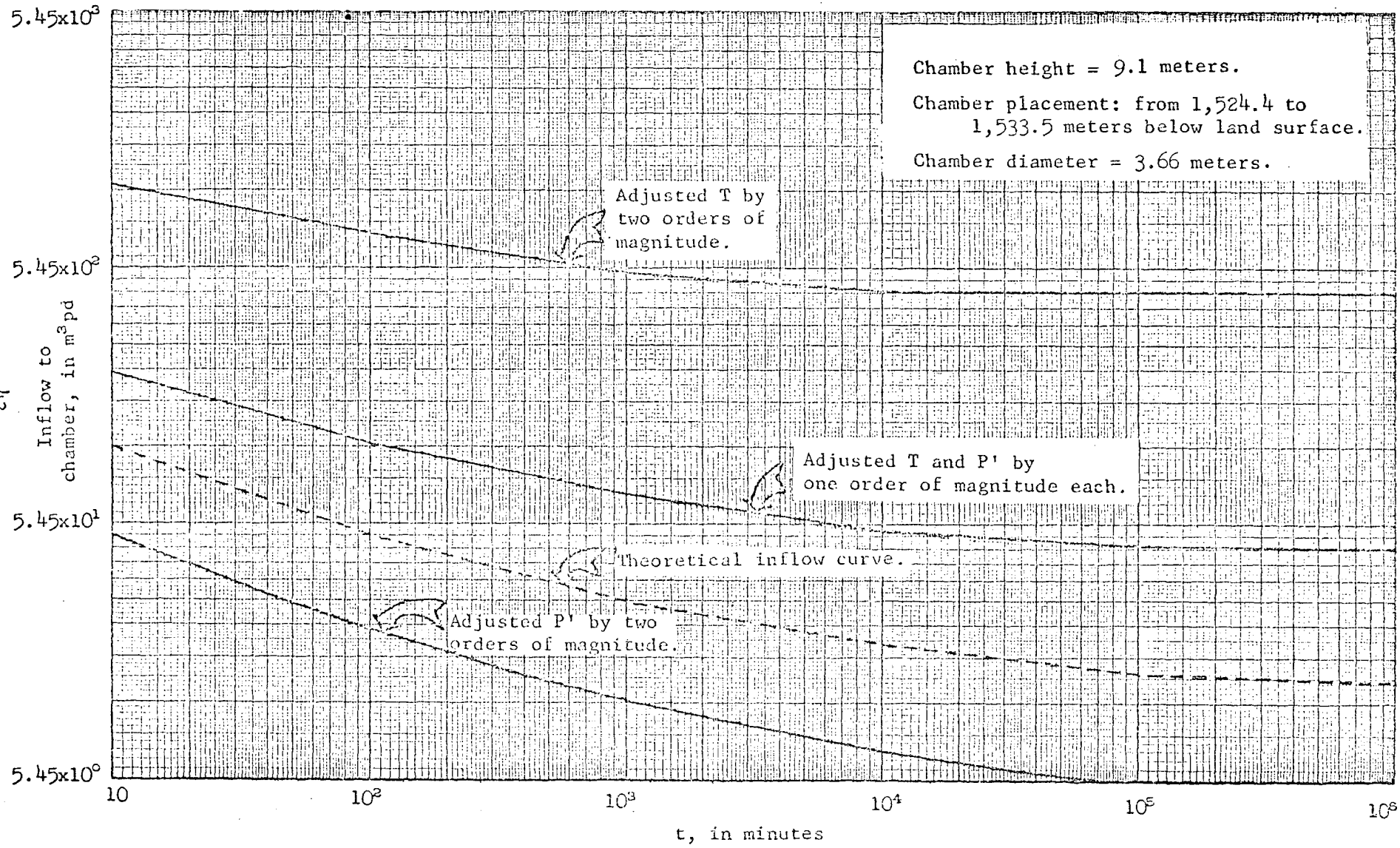

Figure 29.--Anticipated inflow to cylindrical chamber in interval 1,521.3 to 1,539.6 m, hole UCe-20, Hot Creek Valley, Nevada.

Table 3.--Summary of hydraulic testing in hole UCe-20, Hot Creek Valley, Nevada

Zone	Interval tested (m below lsd)	Static water level[1] ft below lsd	Static water level[1] m below lsd	Relative specific capacity[1] gpm per ft of dd	Relative specific capacity[1] m^3pd per m of dd	Water swabbed gal	Water swabbed m^3	Specific conductance (micromhos per cm at 25°C)	Temperature °F	Temperature °C	Packer bypass[2]	Storage coefficient	Transmissivity gpd per ft	Transmissivity m^3pd per m	Hydraulic conductivity gpd per ft^2	Hydraulic conductivity m^3pd per m^2	Velocity ft pd	Velocity m pd	Rock type
13[3]	213.4- 219.5	340±	104±	0.005	0.089	--	--	--	--	--	No	6.10×10^{-3}	6.23×10^{-1}	7.73×10^{-3}	3.11×10^{-2}	1.27×10^{-3}	8.2×10^{-4}	2.5×10^{-4}	Alluvium
		--	--	--	--						No								
14[3]	670.7- 676.8	--	--	e.00004	e.00072	--	--	--	--	--	No	$e6.10\times10^{-6}$	$e5.03\times10^{-5}$	$e6.25\times10^{-4}$	$e2.50\times10^{-3}$	$e1.02\times10^{-4}$	$e5.6\times10^{-6}$	$e2\times10^{-5}$	Do.
		--	--	--	--						No								
5	1,481.4-1,502.4	--	--	e.0001	e.0018	--	--	--	--	--	No	$e3.35\times10^{-4}$	$e2.0\times10^{-3}$	$e2.48\times10^{-4}$	$e2.89\times10^{-4}$	$e1.18\times10^{-5}$	$e1.9\times10^{-6}$	$e5.9\times10^{-7}$	Welded tuff
		--	--	--	--						No								
1	1,481.4-1,617.7	--	--	e.070	e1.27	--	--	--	--	--	--	4.67×10^{-3}	10.9	1.35×10^{-1}	2.43×10^{-2}	9.9×10^{-4}	1.62×10^{-4}	4.95×10^{-5}	Do.
		--	--	--	--						No								
4	1,502.4-1,538.4	--	--	e.0005	e.0089	--	--	--	--	--	No	4.89×10^{-5}	3.53×10^{-1}	4.38×10^{-3}	2.99×10^{-3}	1.22×10^{-4}	2.0×10^{-5}	6.1×10^{-6}	Do.
		--	--	--	--						No								
10	1,521.3-1,539.6	--	--	e.0003	e.0054	--	--	--	--	--	No	5.12×10^{-5}	1.76×10^{-1}	2.19×10^{-3}	2.94×10^{-3}	1.20×10^{-4}	1.97×10^{-5}	6.0×10^{-6}	Do.
		--	--	--	--						No								
11	1,539.6-1,557.9	228	69.5	.018	.32	--	--	--	--	--	No	2.51×10^{-3}	10.6	1.31×10^{-1}	1.75×10^{-1}	7.16×10^{-3}	1.18×10^{-3}	3.6×10^{-4}	Do.
		219	66.8	.022	.39						No								
3	1,539.6-1,617.7	--	--	e.013	e.23	--	--	--	--	--	--	4.67×10^{-3}	7.56	9.38×10^{-2}	2.9×10^{-2}	1.2×10^{-3}	1.97×10^{-4}	6.0×10^{-5}	Do.
		--	--	--	--						No								
2	1,579.0-1,617.7	--	--	e.000015	e.00027	--	--	--	--	--	--	$e4.67\times10^{-7}$	$e7.05\times10^{-2}$	$e8.75\times10^{-4}$	$e5.54\times10^{-4}$	$e2.26\times10^{-5}$	$e5.71\times10^{-6}$	$e1.74\times10^{-6}$	Do.
		--	--	--	--						No								
9	1,625.0-1,829.3	271	82.6	.36	6.44	--	--	--	--	--	--	--	$e3.53\times10^{3}$	e43.8	e5.1	$e2.1\times10^{-1}$	$e3.6\times10^{-2}$	$e1.1\times10^{-2}$	Do.
		262	79.9	--	--						No								
12[4]	1,652.4-1,670.7	215	65.5	High[5]	High[5]	9,000	34	800	93	34	No	--	$e3.02\times10^{3}$	e37.5	e50.2	e2.05	$e3.3\times10^{-1}$	$e1.0\times10^{-1}$	Do.
		215	65.5	High[5]	High[5]						Slight								
8	1,680.0-1,829.3	277	84.5	--	--	--	--	--	--	--	--	--	$e2.12\times10^{3}$	e26.3	e4.31	$e1.76\times10^{-1}$	$e2.9\times10^{-2}$	$e5.8\times10^{-3}$	Do.
		272	82.9	.008	.14						No								
7	1,798.8-1,829.3	--	--	e.002	e.036	--	--	--	--	--	--	6.26×10^{-4}	1.39	1.73×10^{-2}	1.39×10^{-2}	5.67×10^{-4}	9.19×10^{-6}	2.8×10^{-5}	Do.
		--	--	--	--						No								

1/ Upper number from injection; lower number from recovery after swabbing.
2/ Upper-bypass around top packer; lower-bypass around bottom packer.
3/ Perforated casing and cement (two shots per ft).
4/ Sampled for chemical analysis.
5/ High-recovery too rapid to measure.

NOTE: Composite water level = 65.5 meters below lsd.

Explanation:

m - meters
lsd - land-surface datum
ft - feet
gpm - gallons per minute
dd - drawdown
m^3pd - cubic meters per day
gal - gallons
cm - centimeters
°C - degrees Centigrade
°F - degrees Fahrenheit
gpd - gallons per day
ft^2 - square feet
m^2 - square meters
ft pd - feet per day
mpd - meters per day
e - estimated

HOLE HTH-1

Hole HTH-1, at coordinates N. 1,411,443 ft and E. 629,720 ft, Nevada coordinate system, central zone, Nye County, Nevada, penetrated alluvium, densely welded tuff, and tuffaceous sediments. The land-surface elevation at this site is 1,832.6 meters above mean sea level.

Hydrostatic head distribution

The greatest hydraulic potential was measured in the interval from 731.7 to 750.0 meters below land surface. The static water level in this interval was about 167 meters below land surface during testing. The hydraulic potential decreases slightly both above and below this interval. The static water level in the interval 506.1 to 524.4 meters was about 169 meters below land surface. The static water level in the interval 899.4 to 917.7 meters was about 170 meters below land surface.

Tracejector survey

Significant results were obtained from tracejector surveys under both pumping and static conditions. The survey under static conditions indicates that in an interval of densely welded tuff from 731.7 to 750.0 meters, the flow probably is primarily lateral. However, there is potential for vertical flow from this interval both upward into the alluvium and downward into the tuffaceous sediments. During the survey, flow in the borehole from this interval was upward at a rate of more than 15 m^3pd and downward at a rate of more than 20 m^3pd.

A tracejector survey made while pumping water at a rate of about 290 m^3pd indicates that most of the water came from the intervals 213.4 to 259.1 meters and 289.6 to 350.6 meters (fig. 30). There was no measurable contribution from the interval 1,094.5 to 1,117.4 meters.

Specific capacity

The well was pumped to determine aquifer characteristics. A bridge plug was set at 426 meters below land surface and the pump intake was at 366 meters; therefore, water was pumped only from the perforated intervals 213.4 to 259.1 meters and 289.6 to 350.6 meters. The average discharge was 665 m^3pd, and the drawdown was 5.5 meters after about 7 days of pumping. Therefore, the specific capacity during this test was about 121 m^3pd per m of drawdown.

Hydraulic characteristics

The analyses of data from injection into individual intervals in hole HTH-1 are presented in figures 31-39. The parameters r_c = 3.02 cm and r_s = 12.22 cm are constant, and the variable parameters are shown on the figures.

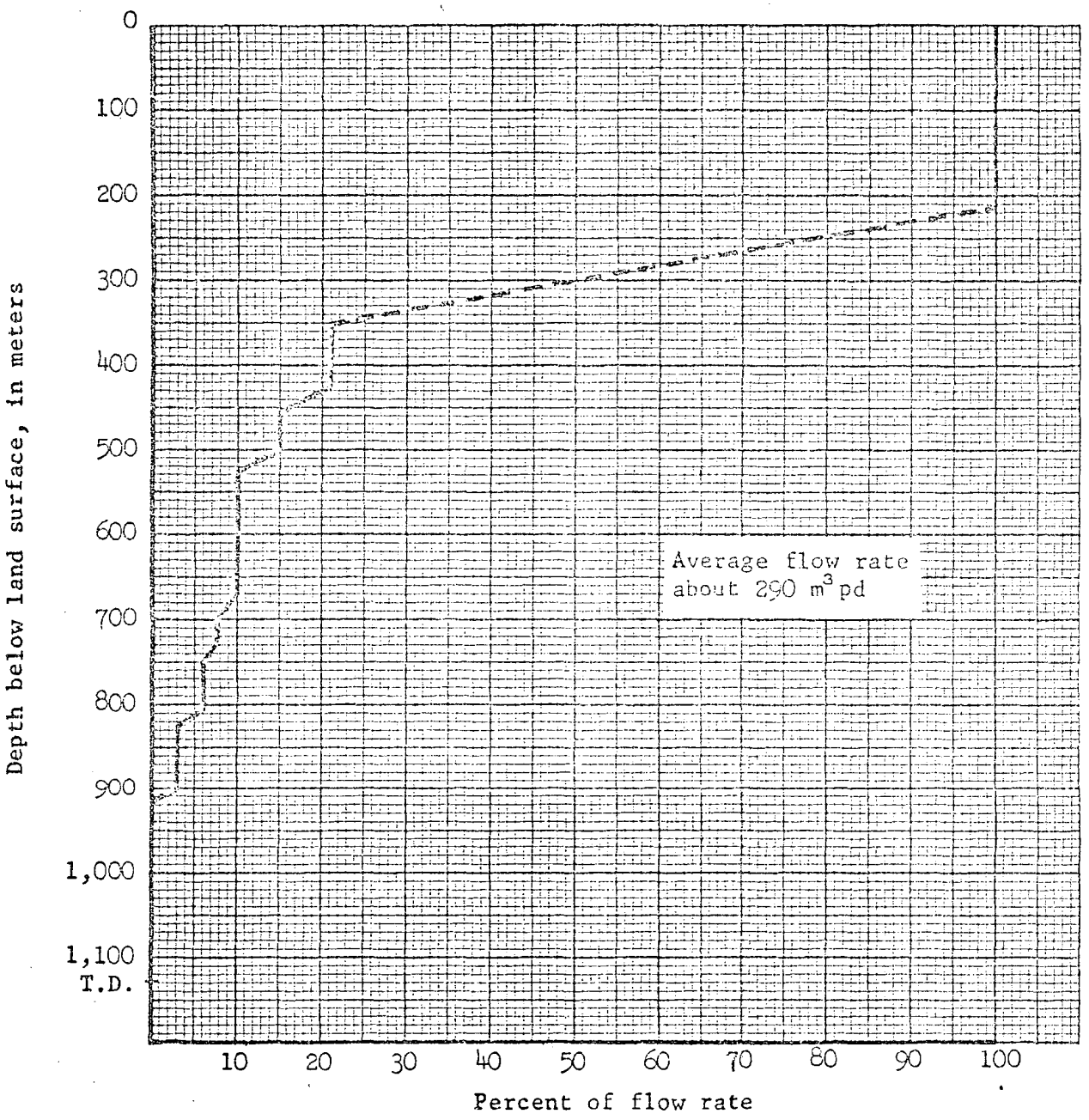

Figure 30.--Tracejector survey of hole HTH-1, Hot Creek Valley, Nevada, while pumping.

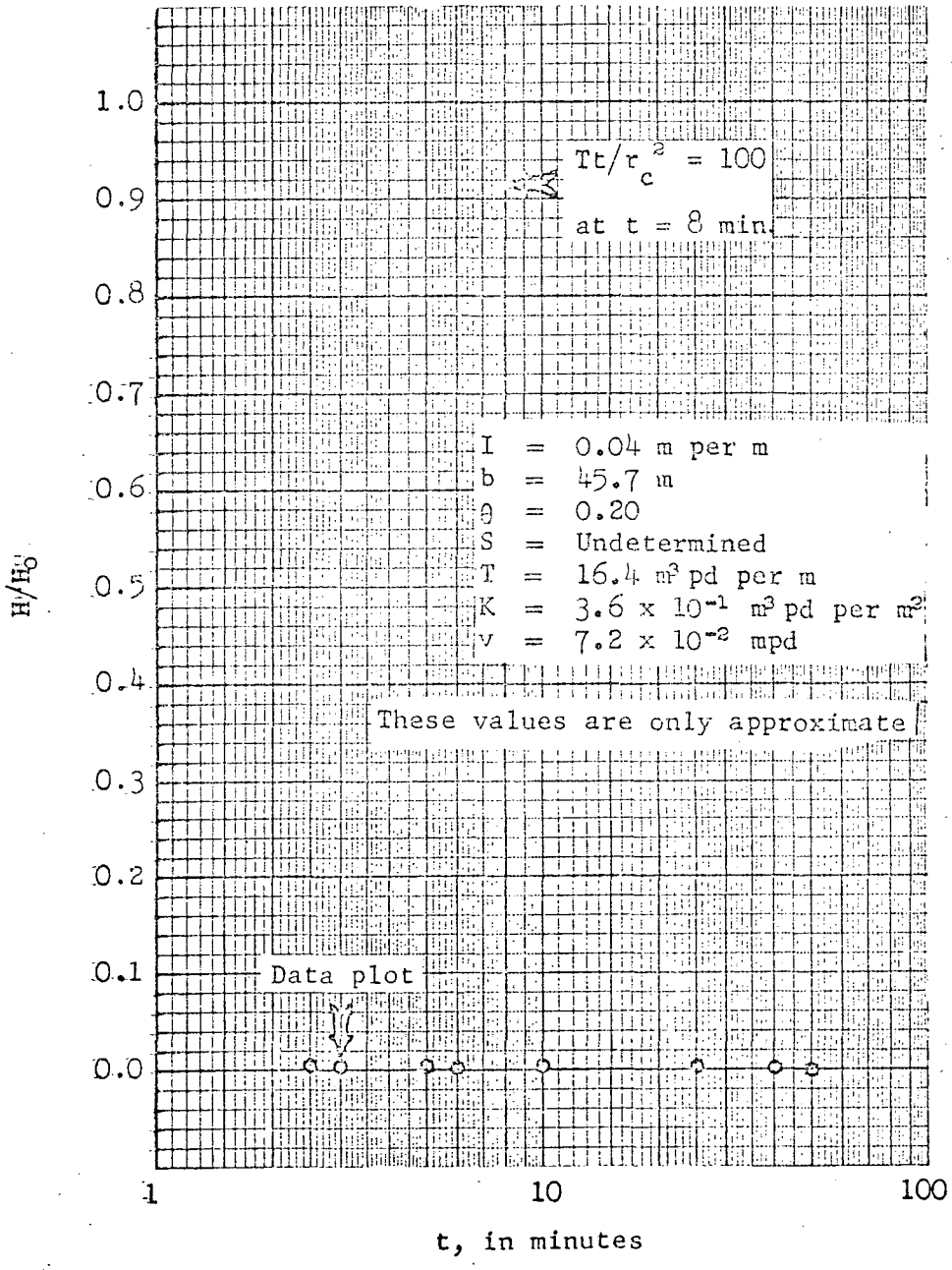

Figure 31.--Injection test of interval 213.4 to 259.1 m, hole HTH-1, Hot Creek Valley, Nevada.

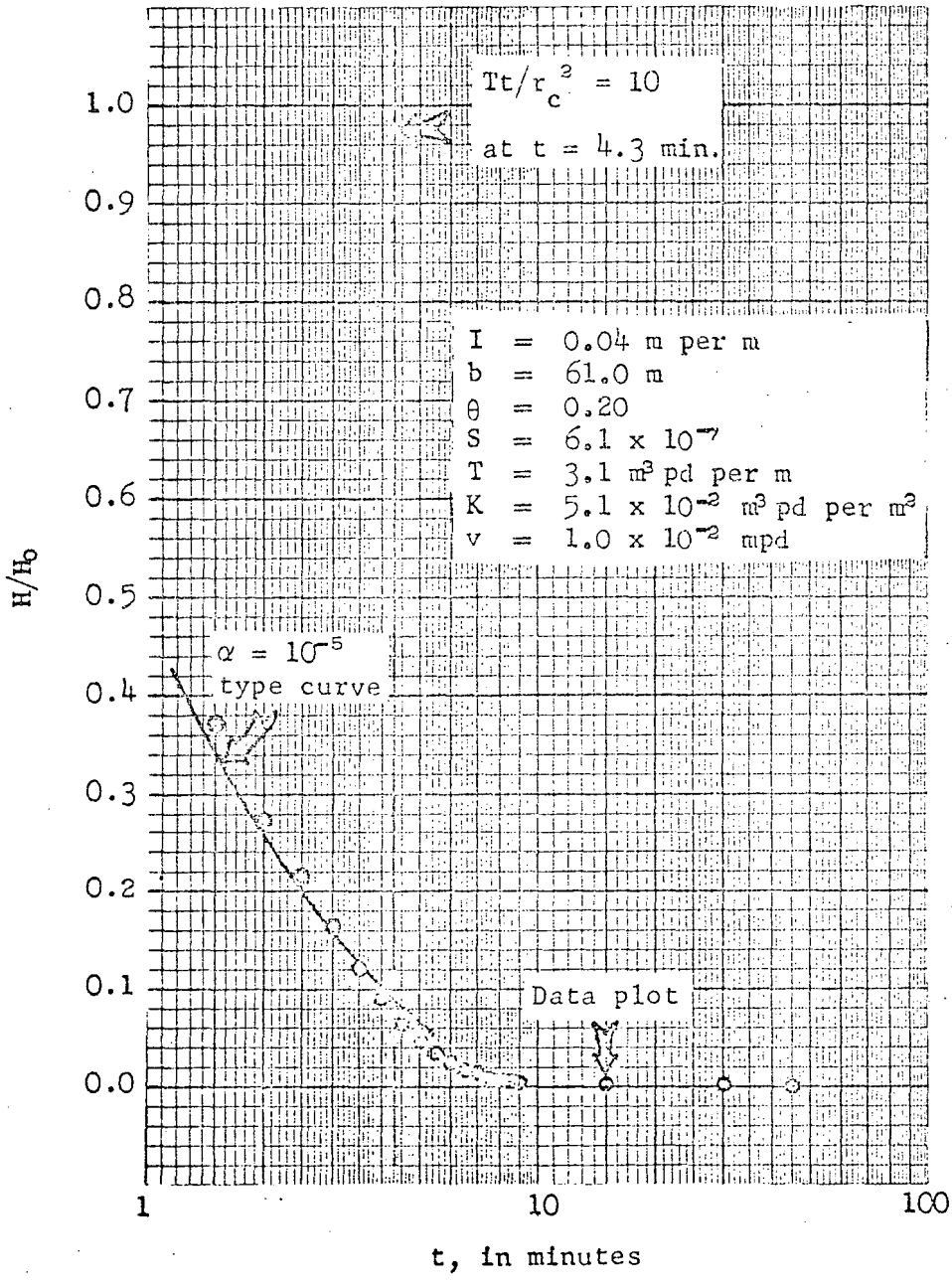

Figure 32.--Injection test of interval 289.6 to 350.6 m, hole HTH-1, Hot Creek Valley, Nevada.

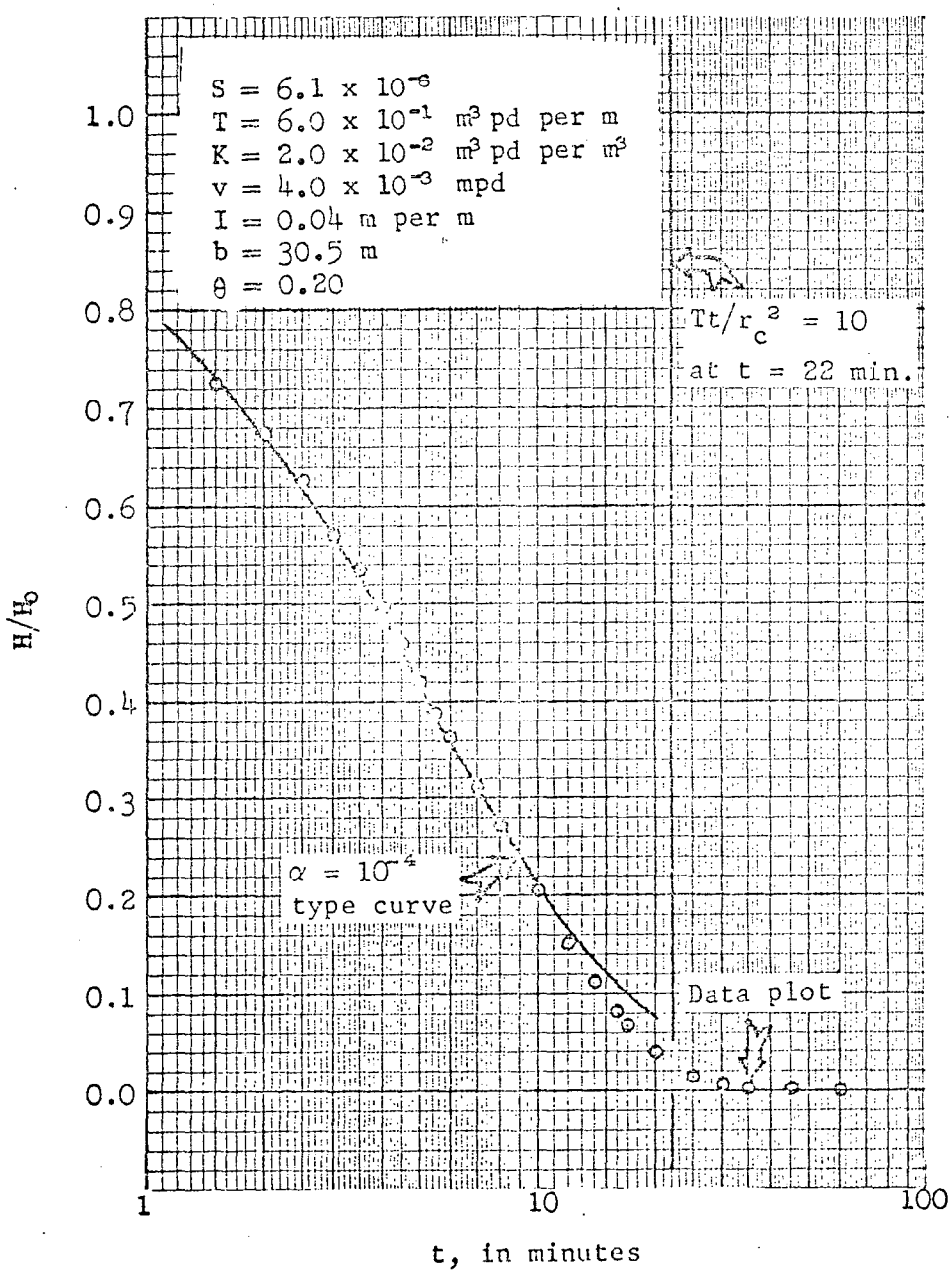

Figure 33.--Injection test of interval 426.8 to 457.3 m, hole HTH-1, Hot Greek Valley, Nevada.

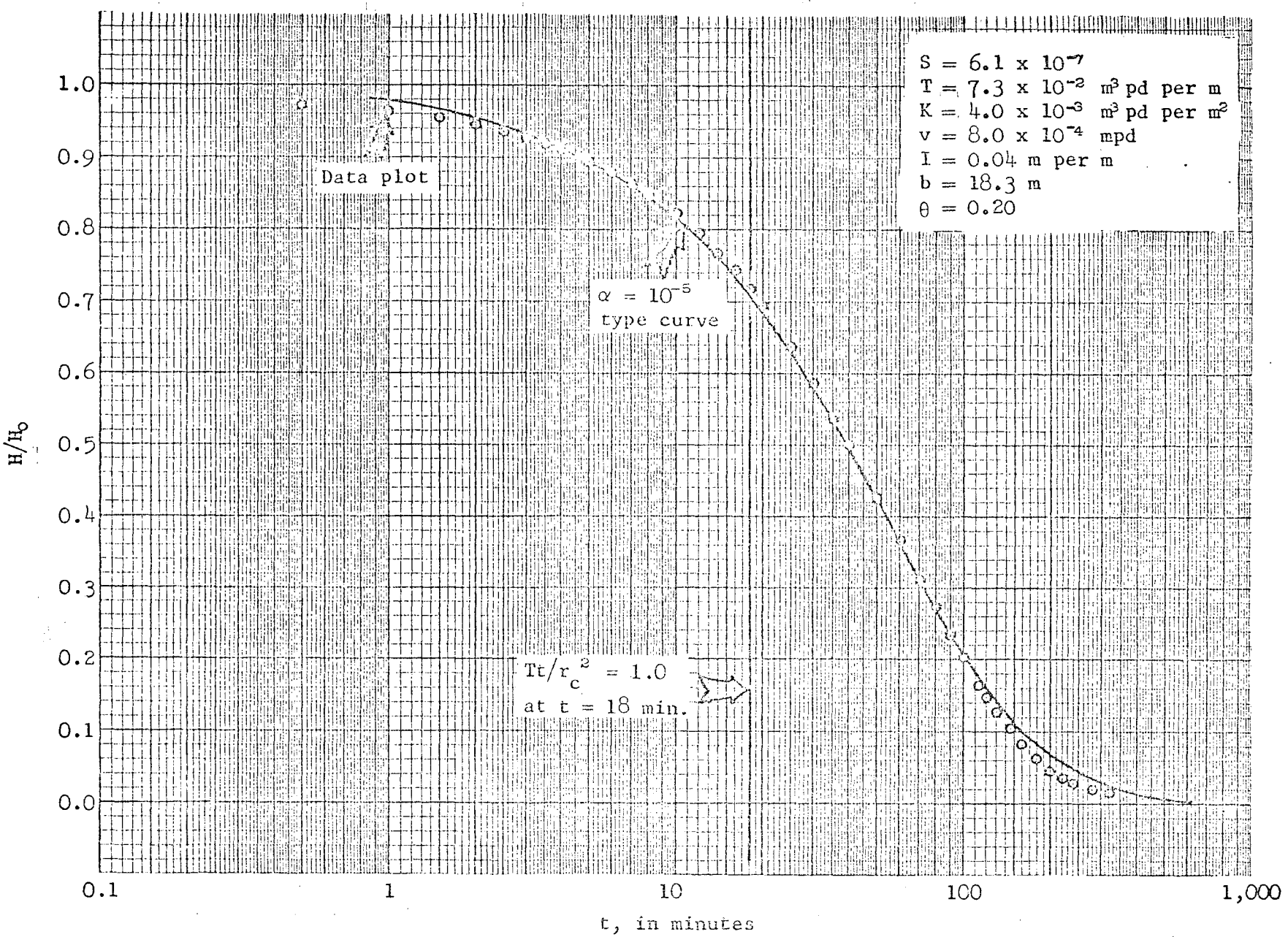

Figure 34.--Injection test of interval 506.1 to 524.4 m, hole HTH-1, Hot Creek Valley, Nevada.

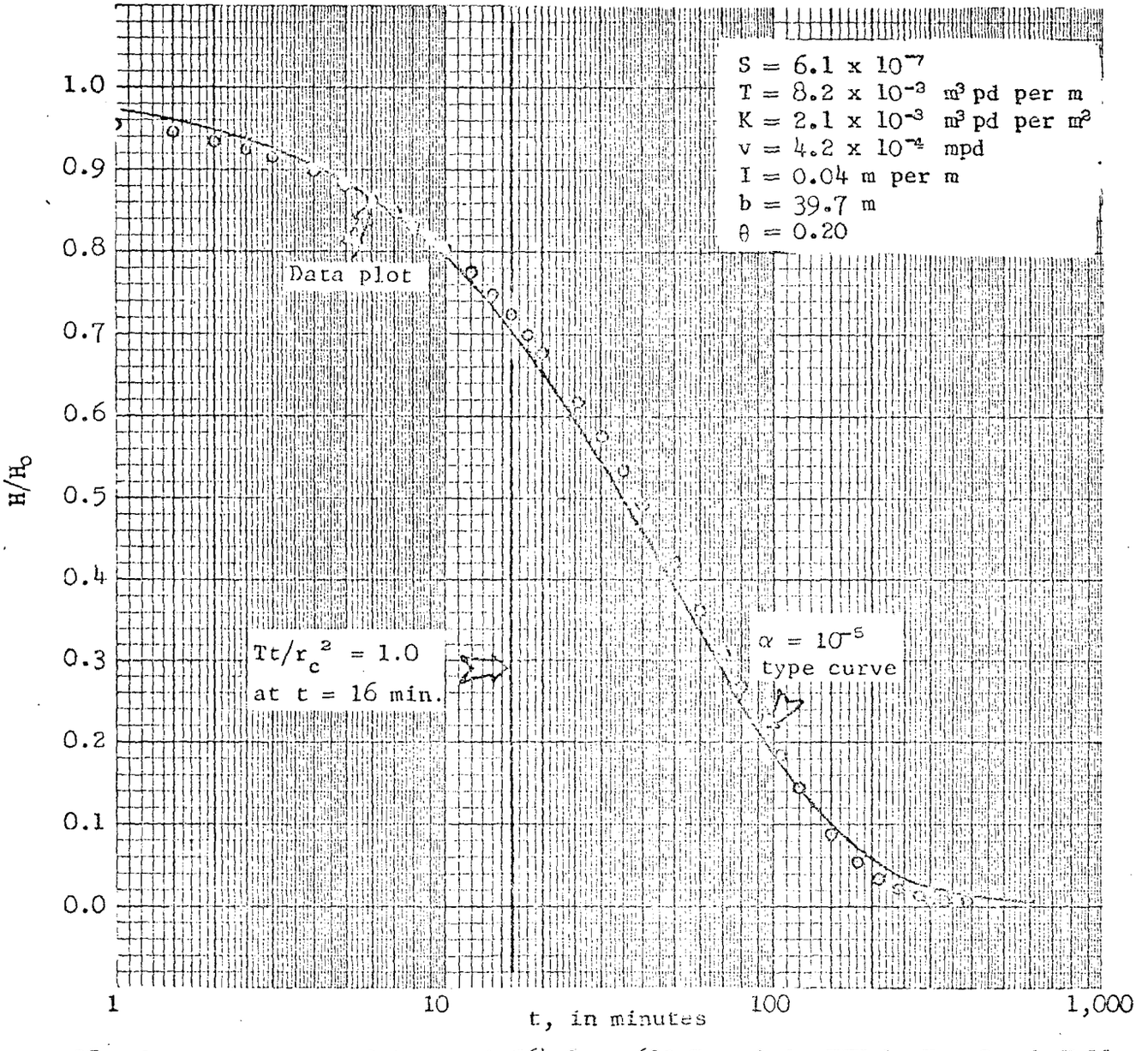

Figure 35.--Injection test of interval 564.0 to 603.7 m, hole HTH-1, Hot Creek Valley, Nevada.

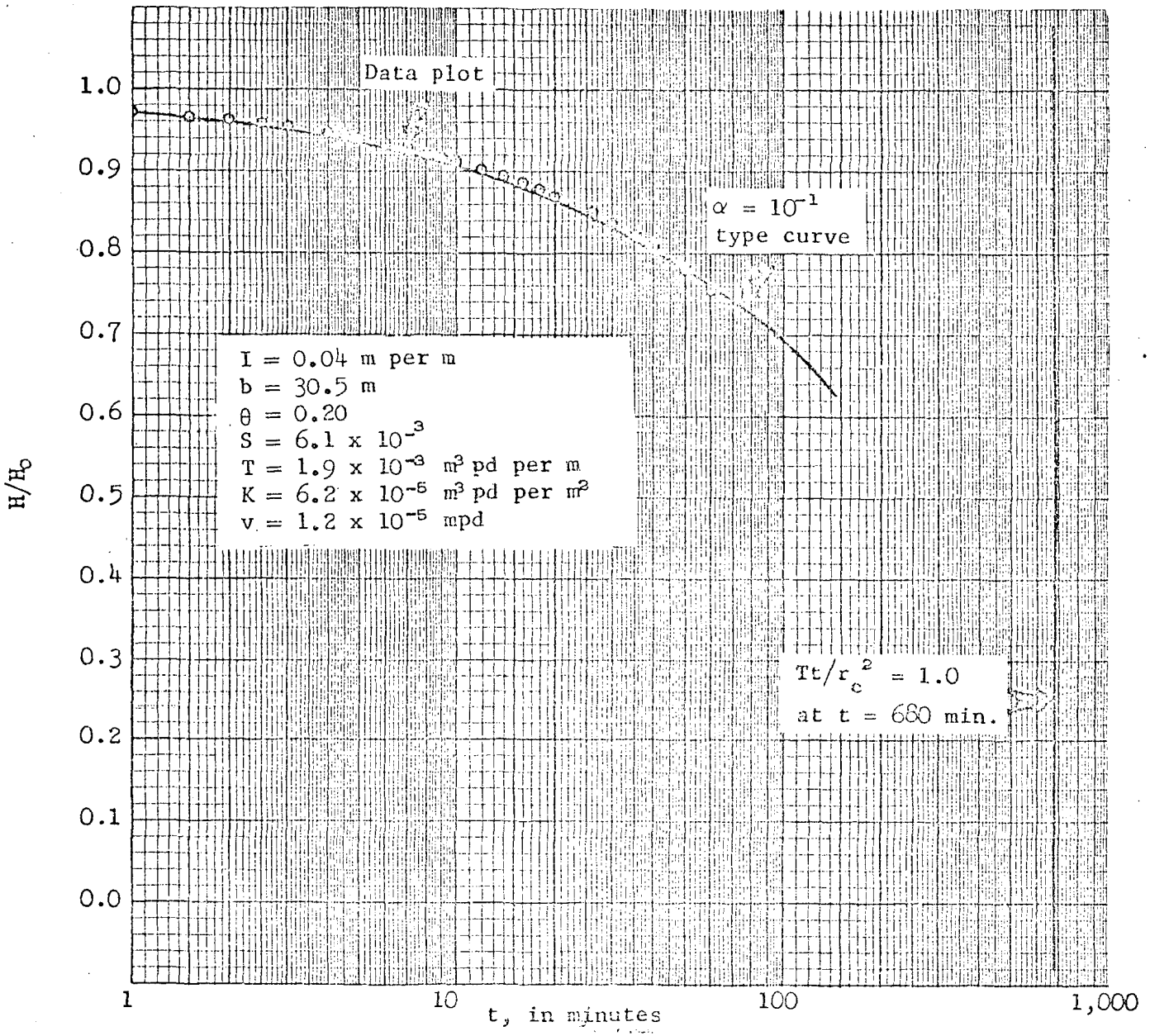

Figure 36.--Injection test of interval 670.7 to 701.2 m, hole HTH-1, Hot Creek Valley, Nevada.

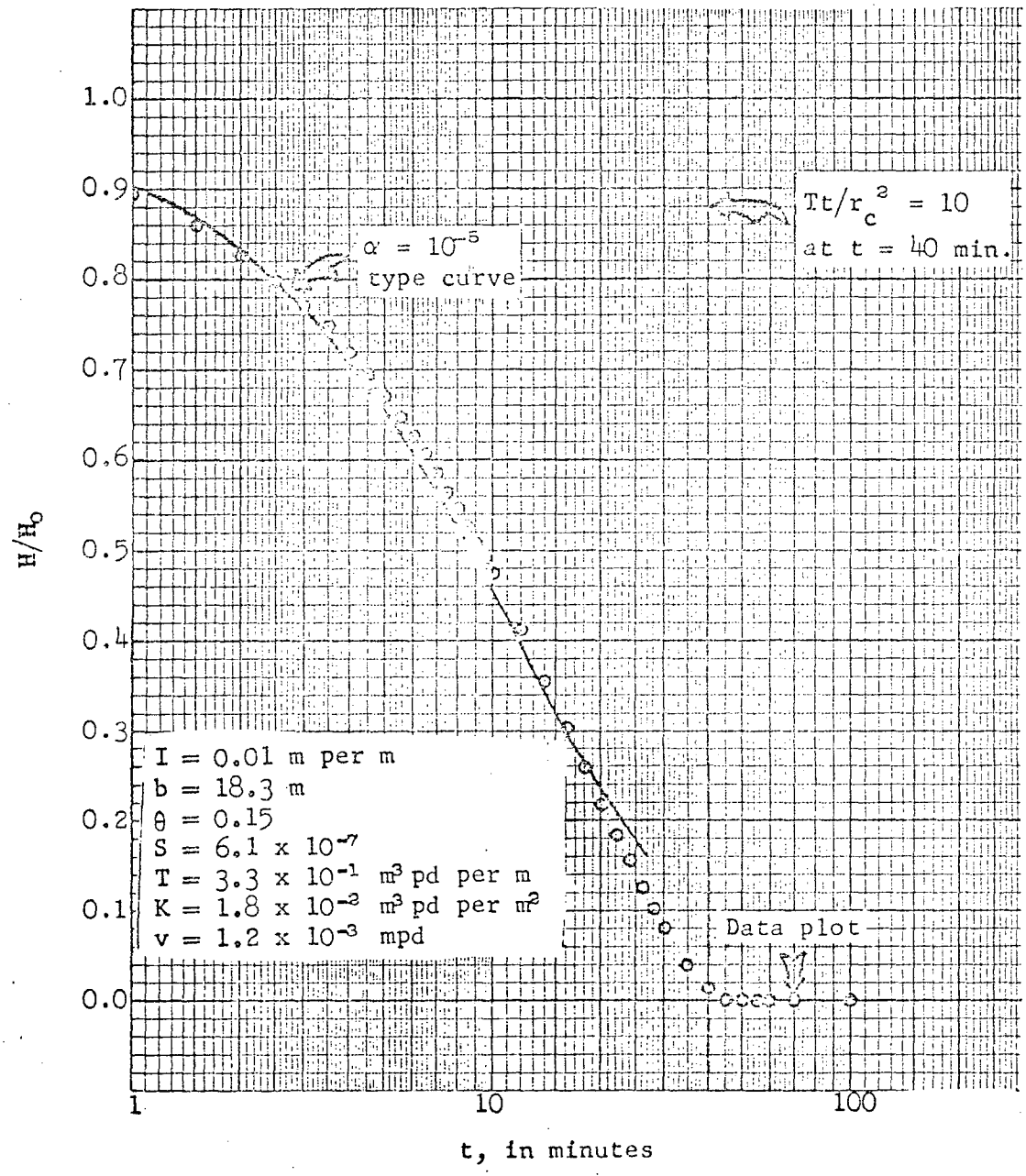

Figure 37.--Injection test of interval 731.7 to 750.0 m, hole HTH-1, Hot Creek Valley, Nevada.

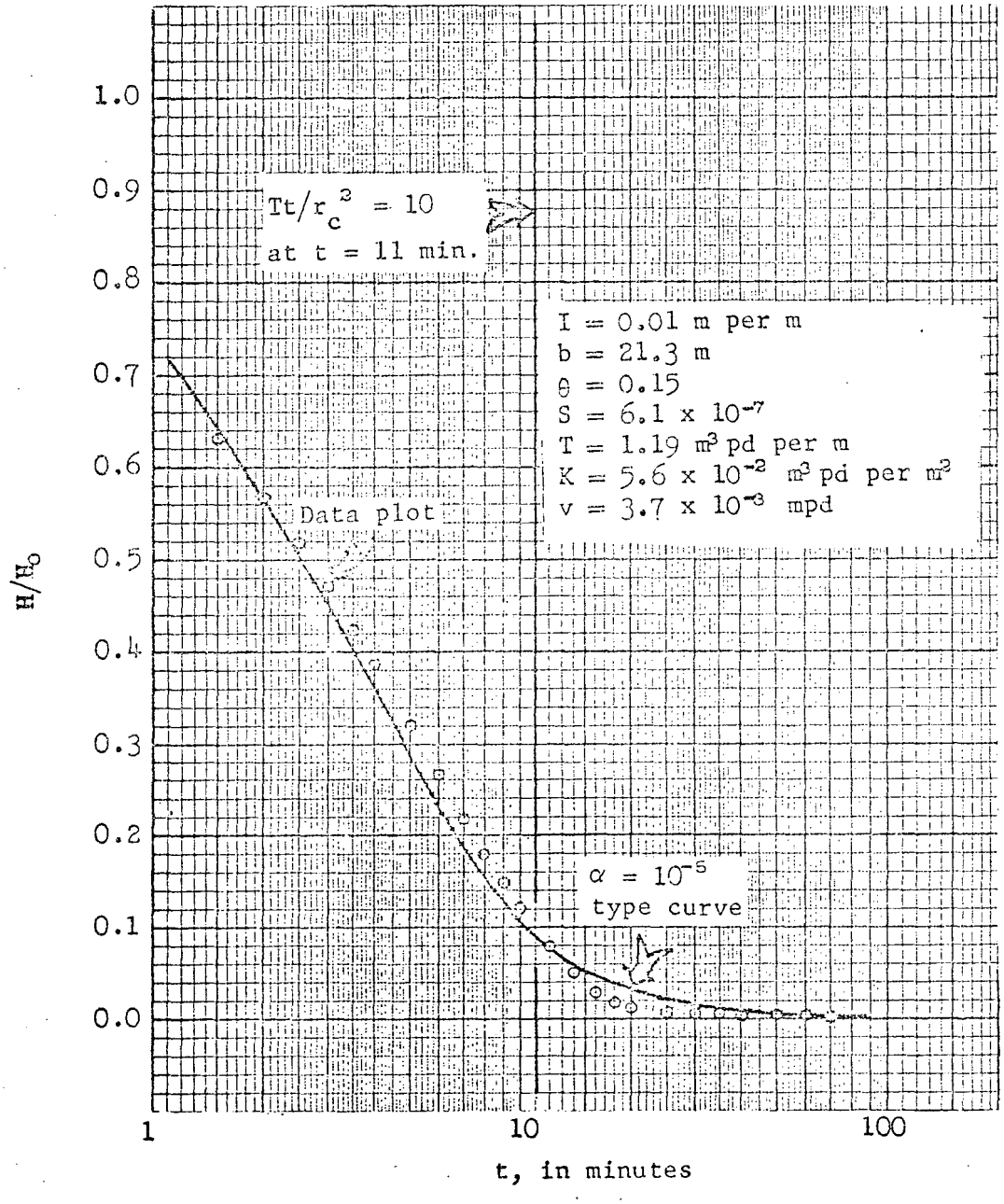

Figure 38.--Injection test of interval 804.9 to 826.2 m, hole HTH-1, Hot Creek Valley, Nevada.

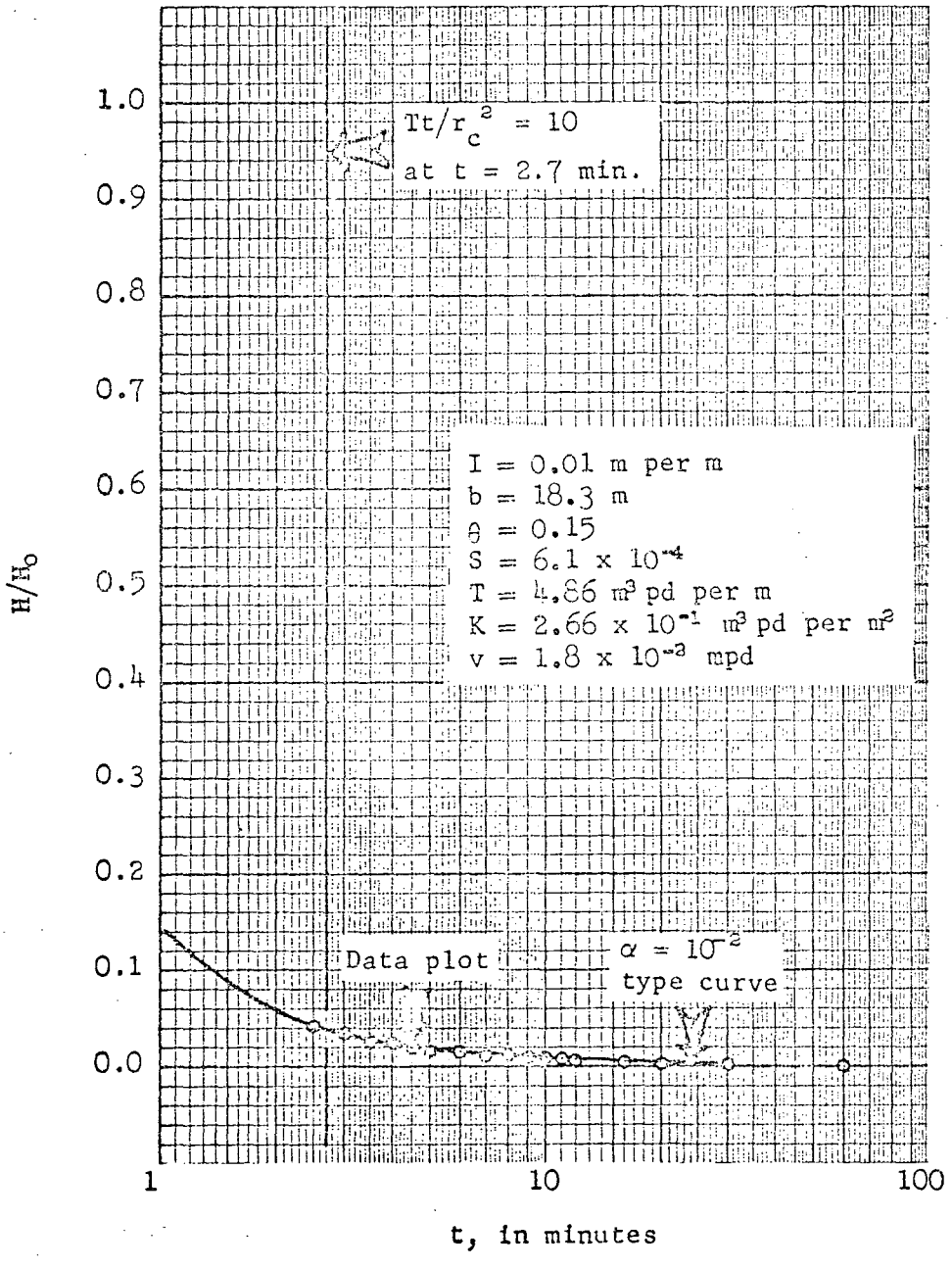

Figure 39.--Injection test of interval 899.4 to 917.7 m, hole HTH-1, Hot Creek Valley, Nevada.

Aquifer performance test in holes HTH-1 and HTH-2

Physical conditions

Hole HTH-1, the pumped well, was drilled to a depth of 1,129 meters and penetrated alluvium from 0 to 728.7 meters, densely welded tuff from 728.7 to 752.4 meters, and tuffaceous sediments from 752.4 to 1,129 meters. The well was cased and cemented throughout its entire depth, after which specific intervals were shot perforated. The perforated intervals were selected as being the most permeable as inferred by the geophysical logs. Isolated tests of hydraulic characteristics showed that the intervals 289.6 to 350.6 meters and 213.4 to 259.1 meters were the most permeable. In order to concentrate the effects of the test within the zones of principal interest, these zones were isolated by use of a retrievable bridge packer. A pump was then installed above the packer.

Hole HTH-2 is 153.8 meters from HTH-1 and was used to observe the effects of pumping hole HTH-1. Drilled to a depth of 304.9 meters, it penetrated alluvium. The well was cased with blank casing from 0 to about 152 meters and with slotted casing from about 152 meters to 304.9 meters.

Purpose of the test

This aquifer-performance test was deemed necessary to determine important aquifer characteristics such as transmissivity and hydraulic conductivity from which rate of ground-water and contaminant movement could be predicted.

Type of test and conditions

The aquifer performance test consisted of pumping well HTH-1 for a period of 10,008 minutes and measuring water-level change in wells HTH-1 and HTH-2 during both pumping and recovery after pumping. The conditions of the test were variable drawdown, with time, at a constant discharge. The average pumping rate was 665 m^3pd. Some difficulties arose toward the end of the test when the rate of discharge fluctuated slightly. The fluctuation was particularly critical because the maximum drawdown in HTH-2 was only 0.171 meters.

Analysis of aquifer-test data

Preliminary analysis of the test data indicated that a mathematical treatment concerned with leaky artesian conditions would be the best means of evaluating the data. Results of this treatment (fig. 40) proved to be the most consistent.

Equations applied to leaky-artesian conditions (Walton, 1962) are as follows:

$$T = 114.6QW(u,r/B)/s \qquad \text{and}$$

$$u = 2693r^2S/Tt, \qquad \text{or} \qquad S = Tut/2693r^2$$

where:

s = drawdown in observation well, in feet

r = distance from pumped well to observation well, in feet

Q = discharge, in gallons per minute

t = time after pumping started, in minutes

T = coefficient of transmissivity, in gallons per day per foot

S = coefficient of storage of aquifer

W(u,r/B) = well function for leaky artesian aquifers

where:

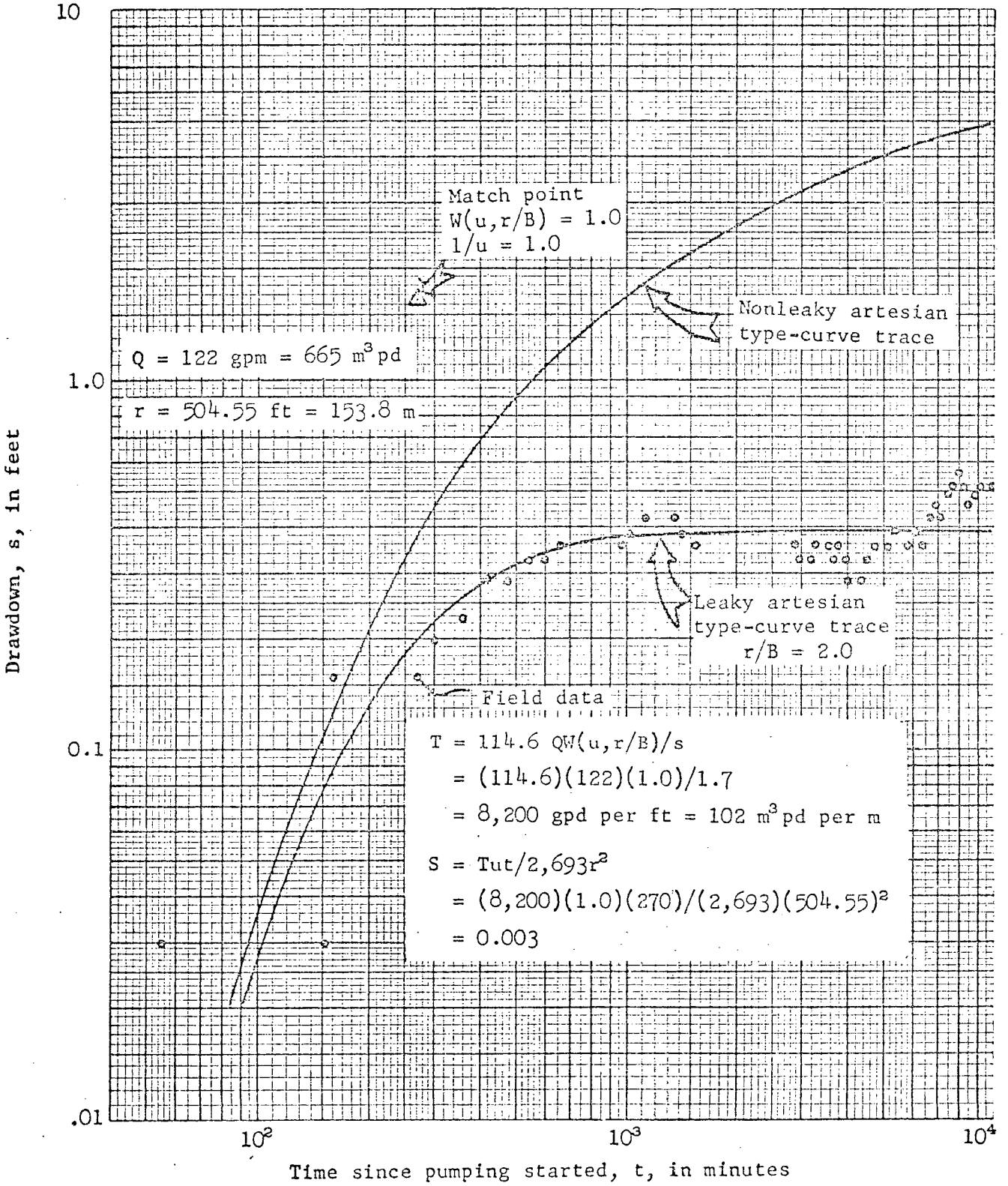

Figure 40.--Time-drawdown graph for observation well HTH-2, Hot Creek Valley, Nevada.

$$r/B = r/\sqrt{T/(P'/m')}$$

P' = hydraulic conductivity of confining bed, in gallons per day per square foot

m' = thickness of confining bed through which leakage occurs, in feet.

When the equations are applied to the drawdown data from HTH-2, the observation well, the transmissivity of the aquifer is 102 m^3pd per m and the coefficient of storage of the aquifer is 3×10^{-3}. Converting transmissivity to hydraulic conductivity (K) is simply a matter of dividing the transmissivity (T) by the aquifer thickness (b):

$$K = T/b.$$

However, the complexity of the hydraulic system that was tested through the hydrologic test holes results in a range of values for aquifer thickness from the combined thickness of the most permeable beds (intervals 213.4 to 259.1 meters and 289.6 to 350.6 meters in HTH-1) to the entire saturated thickness from the static water level to the bottom of perforations (350.6 meters) in HTH-1. Therefore, this range in aquifer thickness (106.7 to 182.0 meters) results in a range of hydraulic conductivity from 0.56 to 0.96 m^3pd per m^2:

$$K = T/b = 102/106.7 = 0.96 \text{ m}^3\text{pd per m}^2$$

and $$K = T/b = 102/182.0 = 0.56 \text{ m}^3\text{pd per m}^2.$$

Pore velocity of ground-water movement is computed from the following equation, using Darcy's law:

$$v = KI/\theta$$

where:

v = velocity, in meters per day

I = hydraulic gradient

θ = effective porosity (fractional).

The hydraulic gradient was determined by using elevations of water levels in holes UCe-11, HTH-1, and UCe-17. The gradient is about 4 meters per 100 meters from northwest to southeast, toward the principal drainage in the area. Assuming an effective porosity of 20 percent, considered a reasonable estimate in the type of material tested, the range of velocity of ground-water movement downgradient would be from 0.112 to 0.192 meters per day.

$$v = KI/\theta = (0.56)(0.04)/0.20 = 0.112 \text{ mpd}$$

$$v = KI/\theta = (0.96)(0.04)/0.20 = 0.192 \text{ mpd.}$$

Table 4.--Summary of hydraulic testing in hole HTH-1, Hot Creek Valley, Nevada.

Zone	Interval tested (m below lsd)	Static water level[1] ft below lsd	Static water level[1] m below lsd	Relative specific capacity[1] gpm per ft of dd	Relative specific capacity[1] m^3pd per ft of dd	Water swabbed gal	Water swabbed m^3	Specific conductance (micromhos per cm at 25°C)	Temperature °F	Temperature °C	Packer bypass[2]	Storage coefficient	Transmissivity gpd per ft	Transmissivity m^3pd per m	Hydraulic conductivity gpd per ft^2	Hydraulic conductivity m^3pd per m^2	Velocity ft pd	Velocity mpd	Rock type
10[3,4]	213.4- 259.1	551	168.0	High[5]	High[5]	875	3.3	285	72	22.2	No	--	e1.3 x10^3	e16.4	e8.8	e3.6 x10^{-1}	e2.4 x10^{-1}	e7.2 x10^{-2}	Alluvium
		549	167.4	High[5]	High[5]						No								
9[3,4]	289.6- 350.6	551	168.0	0.1	1.79	5,300	20	220	76	24.4	No	6.1 x 10^{-7}	2.5 x10^3	3.1	1.25	5.1 x10^{-2}	3.3 x10^{-2}	1.0 x10^{-2}	Do.
		570	167.7	--	--						No								
8[3,4]	426.8- 457.3	545	167.1	.03	.54	1,100	4.2	440	77	25.0	No	6.1 x 10^{-6}	48.3	6.0 x10^{-1}	4.9 x10^{-1}	2.0 x10^{-2}	1.3 x10^{-2}	4.0 x10^{-3}	Do.
		549	167.4	.01	.18						No								
7[3]	506.1- 524.4	553	168.6	.003	.054	200	.76	610	84	28.9	No	6.1 x 10^{-7}	5.88	7.3 x10^{-2}	9.8 x10^{-3}	4.0 x10^{-3}	2.6 x10^{-3}	8.0 x10^{-4}	Do.
		--	--	.004	.072						No								
6[3]	564.0- 603.7	551	168.0	.003	.054	530	2.0	660	83	28.3	No	6.1 x 10^{-7}	6.61	8.2 x10^{-2}	5.1 x10^{-2}	2.1 x10^{-3}	1.4 x10^{-3}	4.2 x10^{-4}	Do.
		--	--	.005	.089						No								
5[3]	670.7- 701.2	--	--	e.001	e.018	300	1.1	--	--	--	No	6.1 x 10^{-3}	1.53 x10^{-1}	1.9 x10^{-2}	1.5 x10^{-3}	6.2 x10^{-6}	3.9 x10^{-6}	1.2 x10^{-6}	Do.
		e570	e168	--	--						No								
4[3,4]	731.7- 750.0	547	166.8	.01	.18	1,550	5.9	730	81	27.2	No	6.1 x 10^{-7}	26.6	3.3 x10^{-1}	4.4 x10^{-1}	1.8 x10^{-2}	3.9 x10^{-3}	1.2 x10^{-3}	Welded tuff
		--	--	--	--						No								
3[3,4]	804.9- 826.2	555	169.2	.03	.54	7,700	29	500	91	32.8	No	6.1 x 10^{-7}	95.9	1.19	1.37	5.6 x10^{-2}	1.2 x10^{-2}	3.7 x10^{-3}	Tuffaceous sediments
		--	--	--	--						Yes								
2[3,4]	899.4- 917.7	558	170.1	.06	1.07	3,400	13	570	91	32.8	No	6.1 x 10^{-4}	3.91 x10^3	4.86	6.52	2.66 x10^{-1}	5.9 x10^{-2}	1.8 x10^{-2}	Do.
		--	--	--	--						No								
1[3]	1,094.5-1,117.4	--	--	e.0007[5]	e.0036[5]	200	.76	--	--	--	No	--	--	--	--	--	--	--	Do.
		e550	e168	e.0003[5]	e.0054[5]						No								

1/ Upper number from injection; lower number from recovery after swabbing.
2/ Upper-bypass around top packer; lower-bypass around bottom packer.
3/ Perforated casing and cement.
4/ Sampled for chemical analysis.
5/ High-recovery too rapid to measure.
6/ Sand may have plugged ports.

NOTE: Composite water level = 168.6 meters below lsd.

Explanation:

m - meters
lsd - land-surface datum
ft - feet
gpm - gallons per minute
dd - drawdown
m^3pd - cubic meters per day
gal - gallons
cm - centimeters
°C - degrees Centigrade
°F - degrees Fahrenheit
gpd - gallons per day
ft^2 - square feet
m^2 - square meters
ft pd - feet per day
mpd - meters per day
e - estimated

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