ARIZONA DEPARTMENT OF WATER RESOURCES

BASIC DATA SECTION

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BUTLER VALLEY AQUIFER TEST

By

Arizona Department of Water Resources

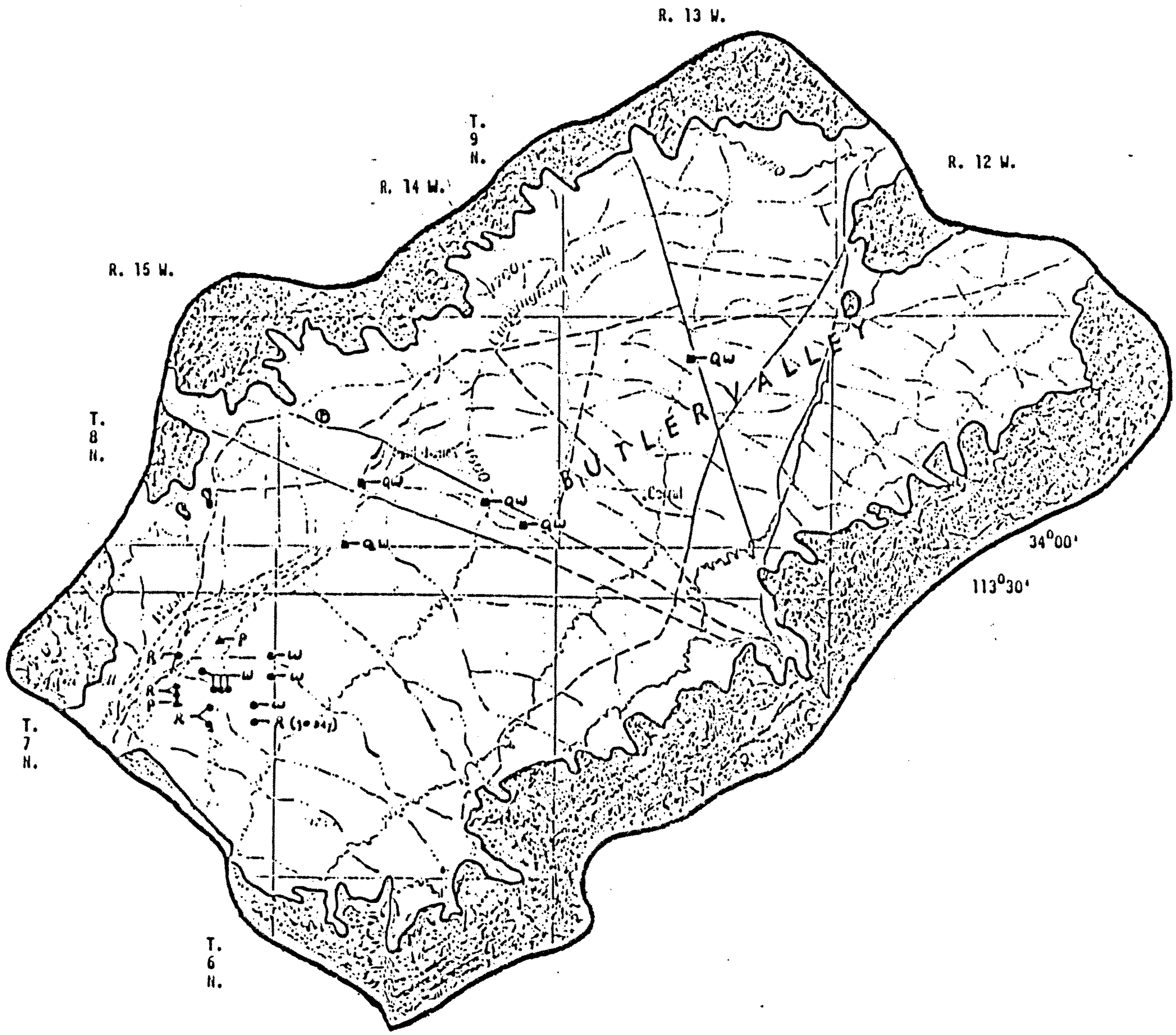
INTRODUCTION

During the period March 16 to April 11, 1985, the Arizona Department of Water Resources collected data from an aquifer test in Butler Valley, Arizona. Butler Valley is an alluvial sediment basin in La Paz County in west-central Arizona about 120 miles west of Phoenix. The aquifer test involved two production wells and thirteen observation wells located in Township 7 North, Range 15 West, Sections 2 and 10-15 (Figure 1). Water-level measurements were collected from all of the wells using electric sounders. A continuous record of depth to water was collected from five of the observation wells using Stevens Type F recorders with one day clocks and a 1:5 gear ratio. A continuous record of depth to water was also collected in one of the observation wells using a 90 day clock recorder for the period February 27 to April 11, 1985. Additionally, water samples were collected from 12 wells throughout the basin and analyzed for common inorganic constituents (Table 1).

The well (B-07-15)02DDC was the first well to begin pumping at 1351 hours on March 16, and water levels were monitored for 37419 minutes until 1330 hours on April 11 when the test was terminated. The well continued pumping for an indeterminate length of time after the test was terminated, so recovery data was never collected. The calculated average rate of discharge was 2208 gallons per minute (GPM). The second production well, (B-07-15)15AAD1, began pumping at 1010 hours on March 27 and was monitored for 14,800 minutes until the well was shut off at 1650 hours on April 6. Recovery data was collected and monitoring continued until 1230 hours on April 11. The calculated average rate of discharge was 1465 GPM. Discharge was measured in both wells using a cox flow meter and the discharge for (B-07-15)02DDC was checked with canal measurements using a Marsh-McBirney current meter.

SUMMARY OF DATA ANALYSIS AND RESULTS

Transmissivity and storativity values were computed using the data collected from one of the production wells and most of the observation wells. Transmissivity values ranged from 35,000 to 66,700 gallons per day per foot (GPD/FT); storativity values ranged from 3.52×10^{-5} to 8.52×10^{-3} (Table 2). The data collected from one of the production wells, (B-07-15)02DDC, and two of the observation wells, (B-07-15)15AAD2 and (B-07-15)15AAD3, were sufficient to calculate transmissivity and storativity by matching type curves for the entire pumping period of the aquifer test. The data collected from six of the other observation wells allowed transmissivity and storativity values to be calculated by matching



EXPLANATION

P

PRODUCTION WELLS

(B-07-15) 02DDC
(B-07-15) 15AAD1

R

RECORDER WELLS

(B-07-15) 10ADA
(B-07-15) 13DBC (90 day)
(B-07-15) 14ACB
(B-07-15) 14DCB
(B-07-15) 15AAD2
(B-07-15) 15AAD3

BEDROCK (VOLCANIC, GRANITIC, METAMORPHIC, OR SEDIMENTARY ROCK)
Water may occur in weathered or fractured zones, joint systems, or thin alluvium overlying consolidated rocks

W

ADDITIONAL OBSERVATION WELLS

(B-07-15) 11CAA
(B-07-15) 11DCD
(B-07-15) 11DDC
(B-07-15) 11DDD
(B-07-15) 12AAD
(B-07-15) 12DAD
(B-07-15) 13ACB

QW

ADDITIONAL WATER QUALITY WELLS

(B-08-13) 04DDD1
(B-08-14) 20DAB
(B-08-14) 23CDD
(B-08-14) 25BDC
(B-08-14) 29CDD

WATER-BEARING UNITS (CLAY, SILT, SAND, GRAVEL)

ARBITRARY BOUNDARY OF GROUNDWATER AREA

FIGURE 1. -- Map showing Butler Valley basin area and location of wells involved in study.

TABLE 1
WATER QUALITY PARAMETERS

WELL LOCATION	DATE COLLECTED	FIELD CONDUCTANCE (Umhos)	FIELD PH	FIELD ALKALINITY (mg/L)	WATER TEMPERATURE °C	DISSOLVED OXYGEN (mg/L)	LAB FLUORIDE (mg/L)	COLLECTION METHOD
(B-07-15)02DDC	03/20/85	545	7.8	108	27.5	3.2	5.0	Production Well
(B-07-15)10ADA	02/27/85	670	7.1	190	24.5	0.1	7.6	½ HP Submersible
(B-07-15)14ACB	02/28/85	809	8.3	72	26.5	0.3	1.1	½ HP Submersible
(B-07-15)14DCB	03/01/85	651	7.5	138	26.5	0.5	0.6	½ HP Submersible
(B-07-15)15AAD1	04/06/85	960	8.2	96	28.0	*	0.6	Production Well
(B-07-15)15AAD2	02/26/85	840	8.4	57	28.0	0.6	5.7	½ HP Submersible
(B-07-15)15AAD3	02/26/85	930	8.8	49	29.0	0	6.0	½ HP Submersible
(B-08-13)04DDD1	04/11/85	450	8.8	174	29.0	3.3	0.1	Bailer
(B-08-14)20DAB	04/05/85	419	8.2	97	27.5	1.5	9.3	Bailer
(B-08-14)23CDD	04/07/85	575	8.3	105	28.0	2.4	0.5	Bailer
(B-08-14)25BDC	04/07/85	1800	8.2	46	30.0	2.8	0.5	Bailer
(B-08-14)29CDD	04/05/85	502	10.4	110	25.0	0.5	5.9	Bailer

*D.O. Sample not taken, well was pumping air

TABLE 2

SUMMARY OF TRANSMISSIVITY AND STORATIVITY VALUES

WELL LOCATION	GRAPH METHOD	TRANSMISSIVITY (gpd/ft)	STORATIVITY
(B-07-15)02DDC	semi-log (s vs. t)	46,600	
	log-log (s vs. t)	40,200	
	semi-log (residual draw-down vs. t/t′)	54,500	
(B-07-15)10ADA	No Results		
(B-07-15)11CAA	No Results		
(B-07-15)11DCD	log-log (s vs. r^2/t)	43,600	1.54×10^{-3}
	log-log (s vs. t)	43,600	
(B-07-15)11DDC	log-log (s vs. r^2/t)	48,700	2.01×10^{-3}
(B-07-15)11DDD	log-log (s vs. r^2/t)	52,700	2.04×10^{-3}
(B-07-15)12AAD	log-log (s vs. r^2/t)	43,600	2.05×10^{-3}
	log-log (s vs. t)	45,200	
(B-07-15)12DAD	No Results		
(B-07-15)13ACB	log-log (s vs. t)	46,900	
(B-07-15)13DCB	No Results		
(B-07-15)14ACB	log-log (s vs. t)	44,400	
	log-log (recovery vs. t)	62,200	
(B-07-15)14DCB	No Results		
(B-07-15)15AAD1	No Results		
(B-07-15)15AAD2	semi-log (s vs. t)	50,200	2.07×10^{-4}
	log-log (s vs. t)	48,000	3.52×10^{-5}
	log-log (s vs. t/r^2)	35,000	2.99×10^{-4}
	semi-log (recovery vs. t)	52,265	1.08×10^{-3}
(B-07-15)15AAD3	semi-log (s vs. t)	66,700	4.08×10^{-4}
	log-log (s vs. t)	58,900	6.43×10^{-5}
	log-log (s vs. t/r^2	56,000	4.49×10^{-4}
	semi-log (recovery vs. t)	62,400	1.59×10^{-4}
Distance/Drawdown 02DDC	log-log (s vs. r^2	46,000	6.53×10^{-3}
Distance/Drawdown 15AAD1	log-log (s vs. r^2	54,200	8.52×10^{-3}

type curves to the first part of the pumping period of (B-07-15)02DDC prior to drawdown interference from the pumping of (B-07-15)15AAD1.

The semi-log and log-log data graphs used to derive the transmissivity and storativity values are included in the appendix. Original field data and subsequently corrected and compiled data tables utilized in the analysis of the aquifer test are quite lengthy and are not included in this report. However, they are available upon request from the Basic Data Section of the Department of Water Resources.

Useable results were not obtained from the production well (B-07-15)15AAD1, nor from the remaining observation wells. During the first 180 minutes of pumping the discharge from (B-07-15)15AAD1 varied considerably in the range 1030-1550 GPM. As a result the drawdown also varied considerably. Additionally, measuring conditions for the pumping water-level in this well are less than ideal. Several probes were lost due to an obstruction near the 315 foot level. Coincidentally, when the discharge was constant, measured pumping water-levels never varied more than 1/2 foot from this 315 foot level from 900 minutes after the pump started to 14,800 minutes when the pump was shut off. This same pumping level and obstruction problem were noted in a December 1984 aquifer test (Weesner and others, 1985, Appendix 3, p. 1), but during that test, with a constant discharge, the 315 foot pumping level was reached 7½ minutes after pumping began. Also, collection of a dissolved oxygen sample was not possible at this well, as it was pumping a considerable amount of air. Either an obstruction did not allow an actual pumping level to be measured or perhaps the pump bowls were set near the 315 foot level, causing the pump to cavitate and discharge varying amounts of water and air through the pressurized sprinkler system.

The data gathered during the test from the well, (B-07-15)10ADA, were inconsistent with data gathered from the other wells. The bottom of the well was sounded and the depth was only 235 feet, so the data collected from this site were not used in this analysis. Insufficient data were collected from well (B-07-15)11CAA for proper analysis. This is an abandoned well site for which the location was incorrectly registered with the Arizona Department of Water Resources. Hence, the well had not been located and inventoried prior to the beginning of the pump test. Data collected from well (B-07-15)12DAD were not used because when plotted, the data were so scattered, it was impossible to match to any type curves. The reason for the scattered data is unknown. The well, (B-07-15)13DCB, was the observation well located the greatest distance from the two production wells (see Figure 1, Table 3). Only 0.2-0.3 feet of drawdown occurred at this site during the entire aquifer test. The data gathered

TABLE 3

DISTANCE FROM OBSERVATION WELLS TO PRODUCTION WELLS

Well Location	Distance to (B-07-15)02DDC(Feet)	Distance to (B-07-15)15AAD1(Feet)
(B-07-15)02DDC		7405
(B-07-15)10ADA	4230	4920
(B-07-15)11CAA	3075	4375
(B-07-15)11DCD	5240	4045
(B-07-15)11DDC	5175	4440
(B-07-15)11DDD	5215	5195
(B-07-15)12AAD	6665	11610
(B-07-15)12DAD	7615	10710
(B-07-15)13ACB	7625	7930
(B-07-15)13DCB	10070	8530
(B-07-15)14ACB	6815	2635
(B-07-15)14DCB	9360	3965
(B-07-15)15AAD1	7405	
(B-07-15)15AAD2	7330	100.5
(B-07-15)15AAD3	7240	202

during the test from the well, (B-07-15)14DCB, also were inconsistent with data gathered from the other wells. Hence, results were not obtained.

CONCLUSIONS

Analysis and interpretation of the aquifer test data show that in this area of Butler Valley the aquifer responds as a confined aquifer. Therefore, this area would be unsuitable for surface impoundment of water for the purpose of inducing infiltration recharge, and would be less than ideal for use of injection wells due to the small storage values associated with confined aquifers. Locally confined conditions occur or are suspected to exist in aquifers in other nearby basins in which water-table conditions predominate, and, therefore, unconfined or water-table conditions may exist in some other part of Butler Valley.

DATA DEFICIENCIES

Some changes in data collection might have eased the analysis of the data, and are useful to note to prevent their recurrence in future tests. The Arizona Department of Water Resources was given approximately 24 hours notice that pumping would commence. As a result, not all the wells had the recorders or sounders installed at the beginning of the test. Pre-pumping static levels were not obtained in all wells, nor were enough early-time water-levels collected from the observation wells. The dearth of early-time water-levels was caused partly by insufficient staff on site to measure them and partly by recorders on which the floats hung up in the well bore, and thus did not record any water-levels. The dearth of early-time data for many of the observation wells severely hampered the fitting of type curves to the data as most of the data collected occurred only over one log cycle. Also, the calculation of barometric efficiency was difficult because Arizona Department of Water Resources was not able to place a recording barometer in Butler Valley early enough to get pre-test barometric data to compare to pre-test static water-level data collected on the 90-day recorder. Most of the observation wells were a considerable distance from the production wells, so it might have helped reduce data scatter if water-level measurements were recorded to hundredths of a foot instead of tenths of a foot. Sounder measurements to the nearest tenth of a foot is standard procedure in the Arizona Department of Water Resources.

The most dominant problem during the course of the test was the lack of control over the operation of the pumping wells. Discharge varied greatly and often during the course of the test. This, undoubtedly, is the source of some of the scattering of data collected from the observation wells; the rest is attributable to barometric effects and measurement errors. Future tests in other parts of Butler Valley should include pre-test pumping to debug the production well, the pumping plant and the delivery systems. Finally, using eight day clocks on the Stevens Type F recorders, instead of one day clocks, would have made data reduction and analysis easier and the data would have been just as accurate and reliable.

RECOMMENDATIONS FOR FURTHER WORK

As noted in the section on conclusions, the portion of the aquifer tested in Butler Valley responded as a confined (artesian) aquifer. Such an aquifer is unsuitable for surface-impoundment recharge projects and, depending on a number of factors, may be unsuitable for deep injection. What must be determined before any type of recharge project can proceed is the areal extent of the confined aquifer.

Probably the most effective method of determining the extent of the confined aquifer is through a drilling program. Beginning about one mile east of well (B-08-14)29CDD, drill a series of six inch wells on one mile centers through the entire basin fill to bedrock. The wells should be logged by a geologist, and cased for future use as observation wells. Careful attention must be paid to observe the depth below land surface that first water appears, and the depth below land surface that water stands at when the well is completed. If the water has risen in any of the wells after completion, then confined conditions exist there also.

If the drilling program demonstrates that unconfined conditions may, or do exist, an aquifer test should be conducted. No long or short term aquifer tests have been conducted in parts of Butler Valley other than the southwestern end, although wells exist which might lend themselves to such testing.

Before an aquifer test was conducted, drilling of additional observation wells would be required. One problem noted with the two wells drilled specifically for this observation in (B-07-15) 15AAD is that they were not placed on "log cycle distance" intervals from the pumping well, such as 50 feet and 500 feet, or 100 feet and 1000 feet from the pumping well. Failure to space these wells accordingly diminished their usefulness in analyzing the results of the test, particularly in distance-drawdown analyses. Since water table conditions are anticipated in other parts of Butler Valley, observation wells should be placed at the 50 and 500 foot distances from the pumping well. In order to adequately stress the aquifer, any aquifer test conducted should run 30 to 60 days. A test of that length would probably allow all the observation wells to be affected by pumping from the production well which will aid the determination of the storage properties of the aquifer.

SELECTED REFERENCES

Briggs, P. C., 1969, Ground-water conditions in the Ranegras Plain, Yuma County, Arizona, Arizona State Land Department Water Resources Report 41, 28p.

Lohman, S. W., 1979, Ground-water Hydraulics, U. S. Geological Survey Professional Paper 708, 70p.

Weesner, R., Mock, P., Lawrence, J., and Williams, C., 1985, Butler Valley Aquifer Test, Arizona Department of Water Resources Memorandum, 45p.

Wilkins, D. W., and Webb, W. C., 1976, Maps showing ground-water conditions in the Ranegras Plain and Butler Valley Areas, Yuma County, Arizona-1975, U. S. Geological Survey Open-File Report 76-34, Scale 1:125,000.

APPENDIX I

BUTLER VALLEY
GROUNDWATER SITE INVENTORY

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LOCAL NUMBER	SITE ID	DATE WELL COMPLETED	USE OF WATER	CASING DIAM. (INCHES)	DEPTH OF WELL (FEET)	FINISH	DEPTH TO FIRST OPENING (FEET)	ALTITUDE OF LAND SURFACE (FEET)	WATER LEVEL (FEET)		DATE WATER LEVEL MEASURED
B-07-14 16AAA	335725113425801	03/26/1955	S	6.00	--		--	1618.0	--	-D	02/12/1985
B-07-15 02CBC	335838113475201	--	U	6.00	--		--	1402.0	--	-D	02/12/1985
B-07-15 02DDC	335825113471501	05/13/1964	I	20.00	520	P	300	1425.0	163.10	V-	01/09/1986
B-07-15 09DDD	335729113490601	02/ /1950	U	6.00	145	P	--	1365.0	--	-D	06/29/1984
B-07-15 10ADA	335810113480201	02/ /1966	U	--	680	X	--	1404.0	145.20	V-	01/09/1986
B-07-15 11CAA	335748113473201	05/ /1978	U	18.00	600	P	300	1416.0	155.80	V-	01/09/1986
B-07-15 11DCD	335729113471601	06/ /1978	I	16.00	600	P	300	1427.0	175.20	V-	01/09/1986
B-07-15 11DDC	335729113470801	--	H	10.00	--	P	--	1431.0	176.40	V-	01/09/1986
B-07-15 11DDD	335733113470501	05/12/1966	I	20.00	1002	X	175	1444.0	182.00	V-	01/09/1986
B-07-15 12AAD	335807113455101	05/ /1975	I	--	500	X	--	1478.0	217.30	V-	01/09/1986
B-07-15 12DAD	335744113460201	06/26/1966	I	16.00	673	F	150	1484.0	229.60	V-	01/09/1986
B-07-15 13ACB	335717113462501	04/ /1977	I	18.00	540	P	340	1478.0	216.90	V-	01/09/1986
B-07-15 13DBC	335648113462101	09/21/1977	U	18.00	601	P	366	1493.0	234.30	V-	01/09/1986
B-07-15 14ACB	335713113472901	06/ /1977	U	16.00	570	P	320	1430.0	176.40	V-	01/09/1986
B-07-15 14DCB	334647113572601	--	U	24.00	600	P	--	1440.0	183.10	V-	01/09/1986
B-07-15 15AAD1	335716113460301	06/13/1977	I	16.00	604	P	--	1402.0	151.50	V-	01/09/1986
B-07-15 15AAD2	335718113480401	11/12/1964	U	8.00	600	P	400	1402.0	150.50	V-	01/09/1986
B-07-15 15AAD3	335718113480501	11/15/1964	U	8.00	565	P	400	1402.0	149.90	V-	01/09/1986
B-08-12 06DDA	340407113325801	--	U	7.00	830	P	--	2005.0	--	-D	06/27/1984
B-08-13 03DDD	340334113353401	09/01/1968	U	16.00	1100	P	--	1845.0	--	-D	02/12/1985
B-08-13 04DDD1	340333113363701	09/ /1965	U	18.00	1000	P	--	1790.0	513.20	V-	01/09/1986
B-08-13 04DDD2	340340113364201	09/ /1965	U	16.00	1226	F	331	1765.0	509.40	V-	01/09/1986
B-08-13 20CCA	340058113363701	04/21/1968	U	--	1358	X	--	1738.0	--	-W	02/18/1986
B-08-14 13BCC	340224113404001	07/16/1979	U	--	1341	X	--	1615.0	--	-W	06/26/1984
B-08-14 20DAB	340122113440301	08/ /1943	U	16.00	545	X	--	1522.0	247.80	V-	01/09/1986
B-08-14 21CBB	340119113435001	--	U	6.00	--	X	--	1519.0	--	--	--
B-08-14 23CDD	340059113411901	08/01/1978	U	16.00	500	S	450	1600.0	323.10	V-	01/09/1986
B-08-14 23DAA	340127113404901	04/ /1964	U	16.00	730	P	--	1620.0	--	-D	06/26/1984
B-08-14 23DDD	340058113404701	07/29/1965	U	16.00	1000	P	450	1616.0	346.20	V-	01/09/1986
B-08-14 25BDC	340028113403001	09/21/1968	I	16.00	1500	P	400	1645.0	370.70	V-	01/09/1986
B-08-14 29CDD	340004113443601	07/ /1979	U	20.00	1175	P	365	1490.0	211.40	V-	01/09/1986
B-08-14 36BBB	335959113394401	--	U	6.00	--	F	--	1650.0	--	-D	06/26/1984

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LOCAL NUMBER	DISCHARGE GPM		DATE DISCHARGE MEASURED	TYPES OF LOGS AVAILABLE	TEMP (DEG C)	DATE TEMP MEASURED	SPECIFIC CONDUCTANCE (U-MHOS/CM)	DATE CONDUCTANCE MEASURED	FLUORIDE (MG/L)	DATE FLUORIDE MEASURED
B-07-14 16AAA	--	-	--	--	--	--	--	--	--	--
B-07-15 02CBC	--	-	--	--	--	--	--	--	--	--
B-07-15 02DDC	2475	P	03/31/1985	D	27.5	03/20/1985	545	03/20/1985	5.0	03/20/1985
B-07-15 09DDD	--	-	--	--	--	--	--	--	--	--
B-07-15 10ADA	--	-	--	--	24.5	02/27/1985	670	02/27/1985	7.6	02/27/1985
B-07-15 11CAA	--	-	--	D	24.0	02/18/1986	1090	02/18/1986	3.6	02/18/1986
B-07-15 11DCD	--	-	--	D	--	--	--	--	--	--
B-07-15 11DDC	--	-	--	--	--	--	--	--	--	--
B-07-15 11DDD	--	-	--	D	29.0	08/21/1980	712	09/16/1974	1.8	08/21/1980
B-07-15 12AAD	--	-	--	--	29.0	08/20/1980	--	--	3.9	08/20/1980
B-07-15 12DAD	--	-	--	D	30.5	08/20/1980	--	--	1.1	08/20/1980
B-07-15 13ACB	--	-	--	D	--	--	--	--	--	--
B-07-15 13DBC	--	-	--	D	26.0	02/18/1986	1220	02/18/1986	4.0	02/18/1986
B-07-15 14ACB	--	-	--	D	26.5	02/28/1985	809	02/28/1985	1.1	02/28/1985
B-07-15 14DCB	--	-	--	--	26.5	03/01/1985	651	03/01/1985	0.6	03/01/1985
B-07-15 15AAD1	1427	P	04/06/1985	D	28.0	04/06/1985	960	04/06/1985	0.6	04/06/1985
B-07-15 15AAD2	--	-	--	D G	28.0	02/26/1985	840	02/26/1985	5.7	02/26/1985
B-07-15 15AAD3	--	-	--	D	29.0	02/26/1985	930	02/26/1985	6.0	02/26/1985
B-08-12 06DDA	--	-	--	--	--	--	--	--	--	--
B-08-13 03DDD	--	-	--	--	--	--	--	--	--	--
B-08-13 04DDD1	--	-	--	--	29.0	04/11/1985	450	04/11/1985	0.0	04/11/1985
B-08-13 04DDD2	--	-	--	D	33.0	09/17/1974	548	09/17/1974	0.2	09/17/1974
B-08-13 20CCA	--	-	--	C E F J N S	--	--	--	--	--	--
B-08-14 13BCC	--	-	--	A E J N	--	--	--	--	--	--
B-08-14 20DAB	400	-	--	D	27.5	04/05/1985	419	04/05/1985	9.3	04/05/1985
B-08-14 21CBB	--	-	--	--	--	--	--	--	--	--
B-08-14 23CDD	--	-	--	D	28.0	04/07/1985	575	04/07/1985	0.5	04/07/1985
B-08-14 23DAA	--	-	--	D G	--	--	--	--	--	--
B-08-14 23DDD	3000	-	--	D G	--	--	728	06/26/1984	2.0	06/26/1984
B-08-14 25BDC	--	-	--	D	30.0	04/07/1985	1800	04/07/1985	0.5	04/07/1985
B-08-14 29CDD	--	-	--	A C G I J N	25.0	04/05/1985	502	04/05/1985	5.9	04/05/1985
B-08-14 36BBB	--	-	--	--	35.0	08/20/1980	--	--	0.3	08/20/1980

APPENDIX II

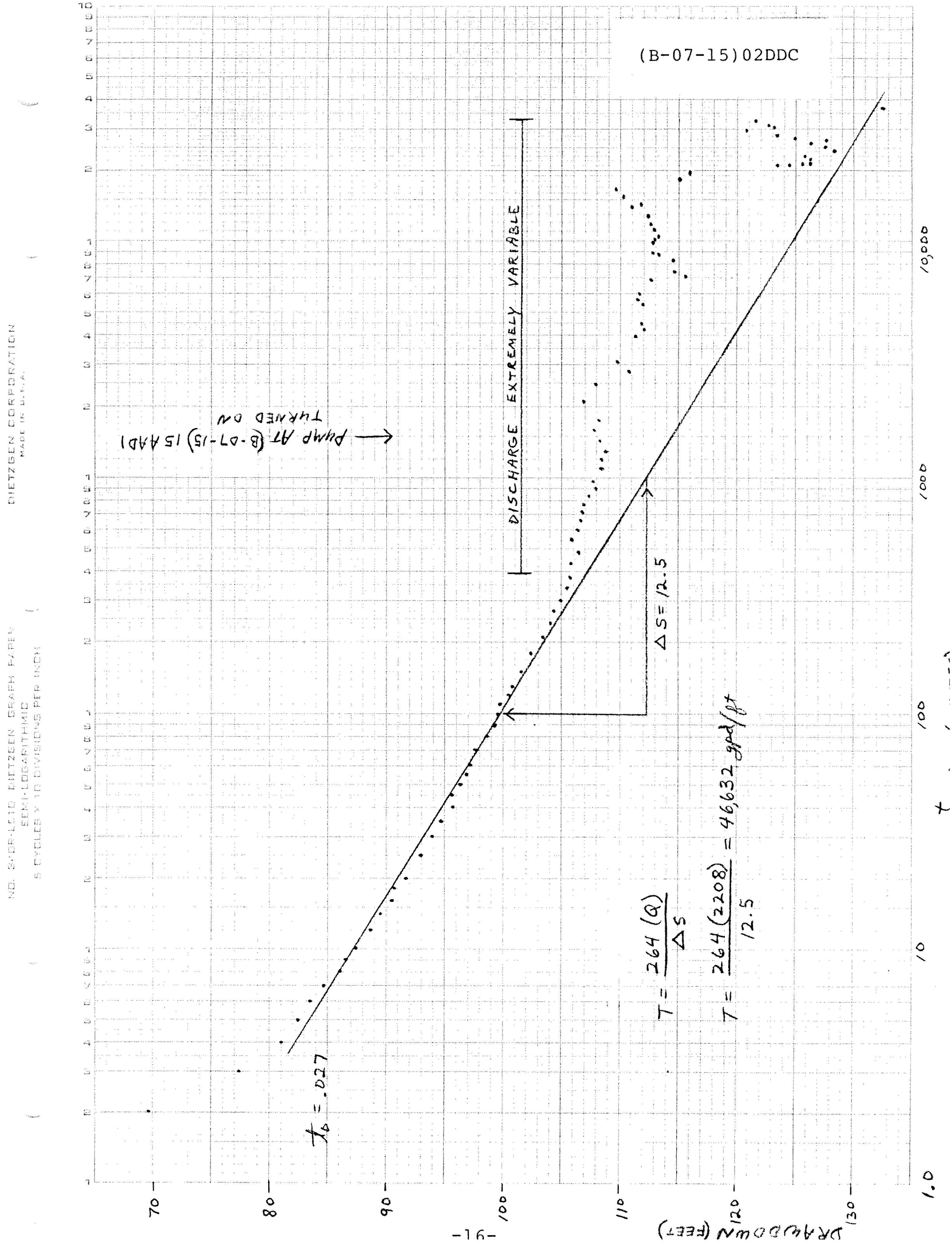
BUTLER VALLEY
HISTORICAL WATER-LEVELS

LOCAL NUMBER	SITE ID	ALTITUDE OF LAND SURFACE (FEET)	WATER LEVEL (FEET)	METH	RMK	SRCE	DATE WATER LEVEL MEASURED	ALTITUDE OF WATER SURFACE (FEET)
B-07-14 16AAA	335725113425801	1618.0			D	A	02/12/1985	
B-07-15 02CBC	335838113475201	1402.0			D	A	02/12/1985	
B-07-15 02DDC	335823113471501	1425.0	149.75	S		U	05/25/1967	1275.25
			149.50	S		U	04/10/1968	1275.50
			149.35	S		U	01/22/1969	1275.65
			149.80	S		U	02/26/1970	1275.20
			150.00	S		U	02/24/1971	1275.00
			148.30	S		U	02/16/1972	1276.70
			150.30	S		U	01/11/1973	1274.70
			150.45	S		U	01/08/1974	1274.55
			152.20	S		U	01/07/1975	1272.80
			155.20	V		U	02/03/1976	1269.80
			157.37	S		U	02/11/1977	1267.63
			158.09			U	02/06/1978	1266.91
			160.10	S		U	01/10/1979	1264.90
			160.79	S		U	02/11/1980	1264.21
			163.38	S		U	02/13/1981	1261.62
			165.30			U	01/25/1982	1259.70
			162.54	S		A	02/12/1985	1262.46
			163.10	V		A	01/09/1986	1261.90
B-07-15 09DDD	335729113490601	1365.0	95.86	S			05/25/1967	1269.14
			94.90	S		U	09/16/1974	1270.10
			96.30	S		U	10/18/1974	1268.70
			96.30	S		U	11/25/1974	1268.70
			94.20	S		U	12/13/1974	1270.80
			94.79	S		U	01/07/1975	1270.21
			94.72	S		U	02/27/1975	1270.28
			94.64	S		U	03/20/1975	1270.36
					D	A	06/29/1984	
B-07-15 10ADA	335810113480201	1404.0	150.20	V		A	06/29/1984	1253.80
			144.70	V		A	02/12/1985	1259.30
			145.20	V		A	01/09/1986	1258.80
B-07-15 11CAA	335743113473201	1416.0	163.70	V		A	03/26/1985	1252.30
			155.80	V		A	01/09/1986	1260.20
B-07-15 11DCD	335729113471601	1427.0	180.90	V		A	06/29/1984	1246.10
			174.94	S		A	02/12/1985	1252.06
			175.20	V		A	01/09/1986	1251.80
B-07-15 11DDC	335729113470801	1431.0	175.40	V		A	02/12/1985	1255.60
			176.40	V		A	01/09/1986	1254.60
B-07-15 11DDD	335733113470301	1444.0	175.50	S		U	05/12/1966	1268.50
			166.72	S		U	05/25/1967	1277.28
			169.90	S		U	01/07/1975	1274.10
			189.60	V		A	06/29/1984	1254.40
			182.20	V		A	02/12/1985	1261.80
			182.00	V		A	01/09/1986	1262.00
B-07-15 12AAD	335807113455101	1478.0	221.10	V		A	06/29/1984	1256.90
			215.90	V		A	02/12/1985	1262.10
			217.30	V		A	01/09/1986	1260.70
B-07-15 12DAD	335744113460201	1484.0	213.88	S		U	05/25/1967	1270.12
			242.50	S		U	09/16/1974	1241.50
			216.20	S		U	11/25/1974	1267.80
			215.85	S		U	12/13/1974	1268.15
			215.10	S		U	01/07/1975	1268.90
			215.43	S		U	02/27/1975	1268.57
			215.52	S		U	03/20/1975	1268.48
			231.90	V		A	06/29/1984	1252.10
			229.00	V		A	02/12/1985	1255.00
			229.60	V		A	01/09/1986	1254.40
B-07-15 13ACB	335717113462501	1478.0	218.60	V		A	06/29/1984	1259.40
			215.40	V		A	02/12/1985	1262.60
			216.90	V		A	01/09/1986	1261.10
B-07-15 13DBC	335648113462101	1493.0	234.60	V		A	06/29/1984	1258.40
			233.40	V		A	02/12/1985	1259.60
			234.30	V		A	01/09/1986	1258.70
B-07-15 14ACB	335713113472901	1430.0	182.00	V		A	06/29/1984	1248.00
			175.60	V		A	02/12/1985	1254.40
			176.40	V		A	01/09/1986	1253.60
B-07-15 14DCB	334647113572601	1440.0	185.60	V		A	06/29/1984	1254.40
			182.30	V		A	02/12/1985	1257.70
			183.10	V		A	01/09/1986	1256.90

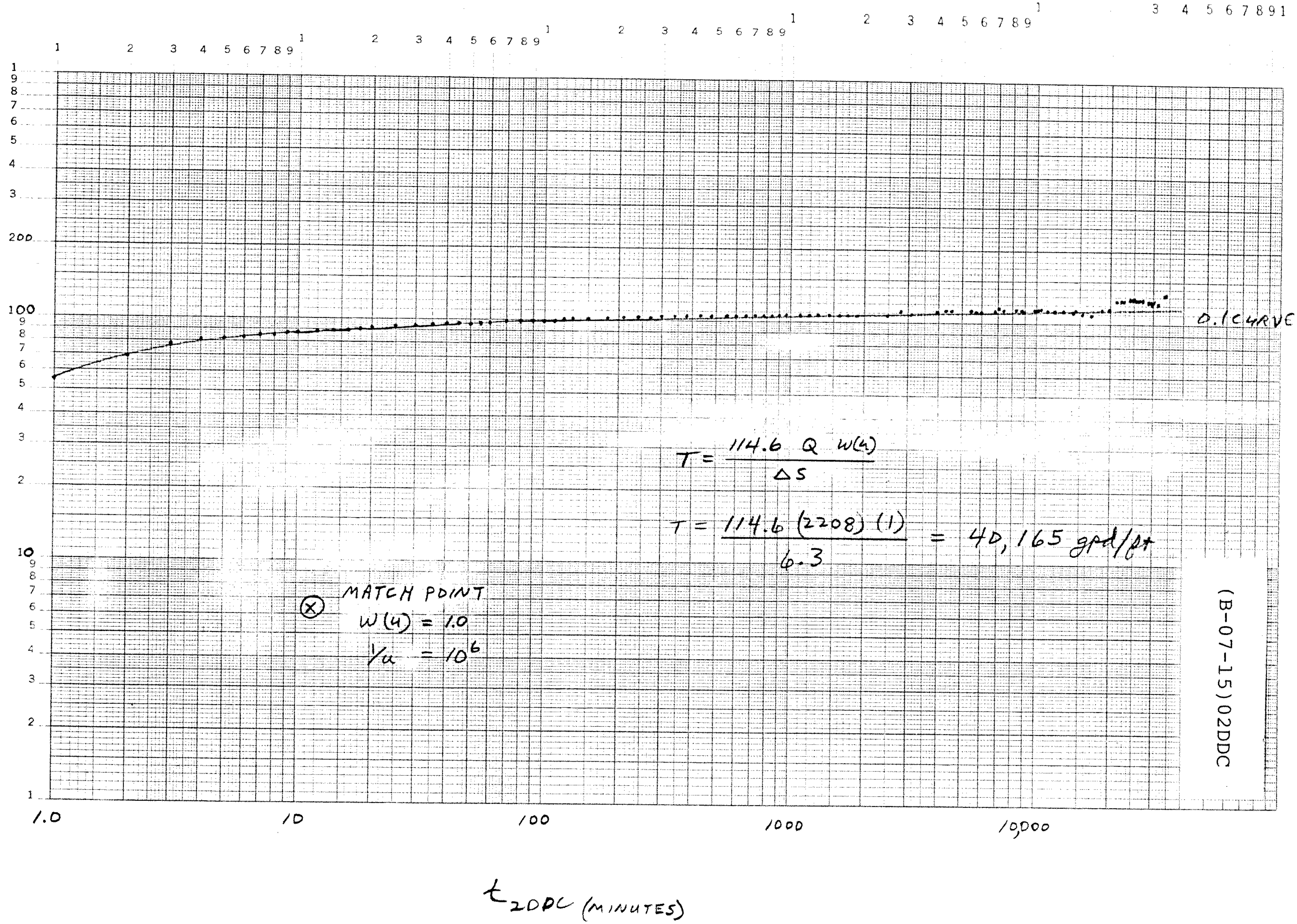
B-07-15 15AAD1	3357181	113480301	1402.0	150.80	V		A	02/12/1985	1251.20
				151.50	V		A	01/09/1986	1250.50
B-07-15 15AAD2	3357181	113480401	1402.0	150.20	V		A	03/16/1985	1251.80
				150.50	V		A	01/09/1986	1251.50
B-07-15 15AAD3	3357181	113480501	1402.0	149.80	V		A	03/16/1985	1252.20
				149.90	V		A	01/09/1986	1252.10
B-08-12 06BDA	3404071	113325801	2005.0	740.00	V		U	02/27/1975	1265.00
						D	A	01/23/1984	
						D	A	06/27/1984	
B-08-13 03DDD	3403341	113353401	1845.0			D	A	06/27/1984	
						D	A	02/12/1985	
B-08-13 04DDD1	3403331	113363701	1790.0	530.00	S	S	U	09/17/1974	1260.00
				516.40	S		U	10/18/1974	1273.60
				516.40	S		U	11/25/1974	1273.60
				514.70	S		U	12/13/1974	1275.30
				513.90	S		U	01/07/1975	1276.10
				524.80	S	S	U	02/27/1975	1265.20
				515.20	S		U	03/20/1975	1274.80
				514.10	V		A	06/27/1984	1275.90
				513.30	V		A	02/12/1985	1276.70
				513.20	V		A	01/09/1986	1276.80
B-08-13 04DDD2	3403401	113364201	1785.0	509.40	V		A	01/09/1986	1275.60
B-08-13 20CCA	3400581	113383701	1738.0			W		02/18/1986	
B-08-14 13BCC	3402241	113404001	1615.0			W	A	06/26/1984	
B-08-14 20DAB	3401221	113440301	1522.0	242.00	S		U	11/09/1948	1280.00
				243.20	S		U	04/10/1968	1278.80
				245.00	S		U	09/17/1974	1277.00
				244.00	S		U	01/07/1975	1278.00
				247.80	V		A	06/24/1984	1274.20
				247.00	V		A	02/12/1985	1275.00
				247.80	V		A	01/09/1986	1274.20
B-08-14 23CDC	3400591	113411901	1600.0	326.94	V		U	02/11/1980	1273.06
				322.90	V		A	02/13/1981	1277.10
				324.30	S		U	01/25/1982	1275.70
				322.40	V		A	06/26/1984	1277.60
				322.50	V		A	02/12/1985	1277.50
				323.10	V		A	01/09/1986	1276.90
B-08-14 23DAA	3401271	113404901	1620.0	340.00	R			04/ /1964	1280.00
				342.30	S			01/11/1973	1277.70
				346.80	S			01/08/1974	1273.20
				339.64	S			02/03/1976	1280.36
						D		02/06/1978	
						D	A	06/26/1984	
B-08-14 23DDD	3400581	113404701	1618.0	335.60	S		U	08/24/1965	1282.40
				345.00	S		U	04/10/1968	1273.00
				352.80	S		U	02/19/1970	1265.20
				380.50	S		U	01/27/1971	1237.50
				332.00	V		U	02/24/1971	1286.00
				334.20	V		U	03/01/1972	1283.80
				344.30	S		U	03/06/1972	1273.70
				346.60	V		U	05/22/1972	1271.40
				349.60	S		U	01/11/1973	1268.40
				341.00			U	02/03/1976	1277.00
				342.90	S		U	02/11/1977	1275.10
				346.23	S		A	06/26/1984	1271.77
				345.40	V		A	02/12/1985	1272.60
				346.20	V		A	01/09/1986	1271.80
B-08-14 25BDC	3400281	113403001	1645.0	368.00				01/ /1969	1277.00
				368.50	S		U	01/23/1969	1276.50
				367.70	S		U	11/25/1974	1277.30
				368.30	S		U	12/13/1974	1276.70
				367.80	S		U	01/07/1975	1277.20
				372.20	V		A	06/26/1984	1272.80
				370.60	V		A	02/12/1985	1274.40
				370.70	V		A	01/09/1986	1274.30
B-08-14 29CDD	3400041	113443601	1490.0	215.20				09/29/1979	1274.80
				210.00	S			02/13/1981	1280.00
				210.80	S			01/25/1982	1279.20
				211.50	V		A	06/29/1984	1278.50
				211.00	V		A	02/12/1985	1279.00
				211.40	V		A	01/09/1986	1278.60
B-08-14 36BBB	3359591	113394401	1650.0			D	A	06/26/1984	

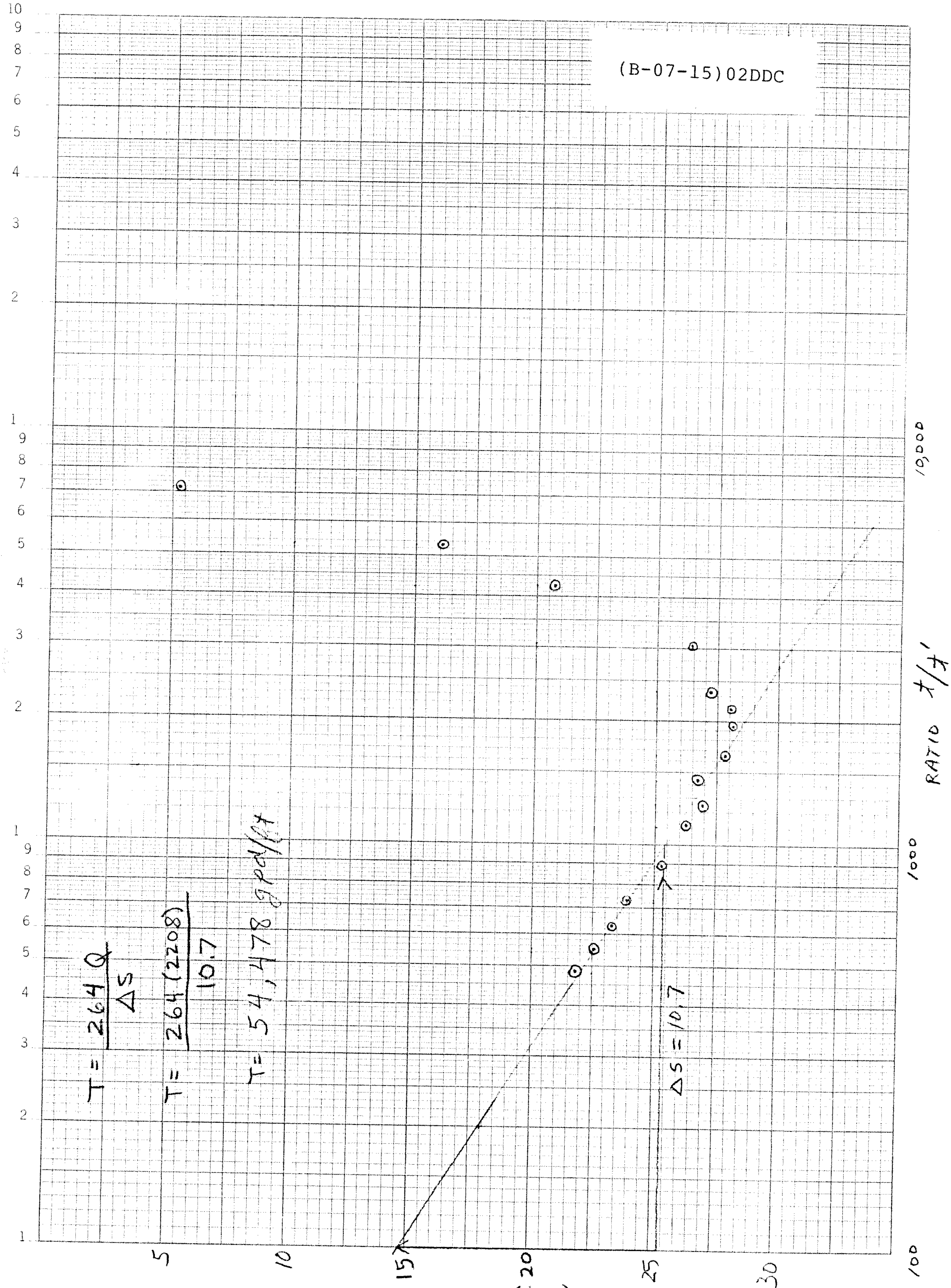
APPENDIX III

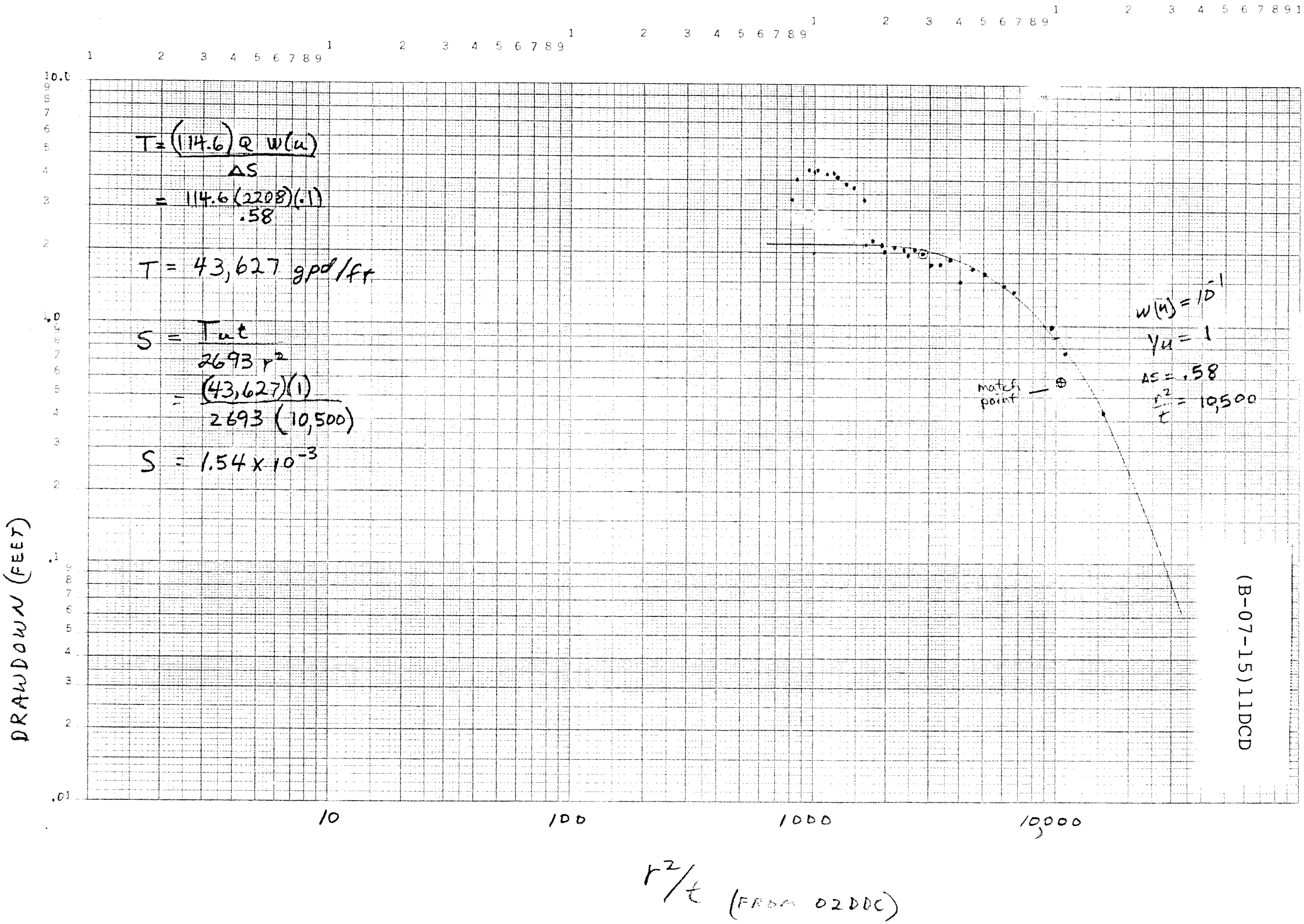
BUTLER VALLEY
AQUIFER TEST DATA GRAPHS

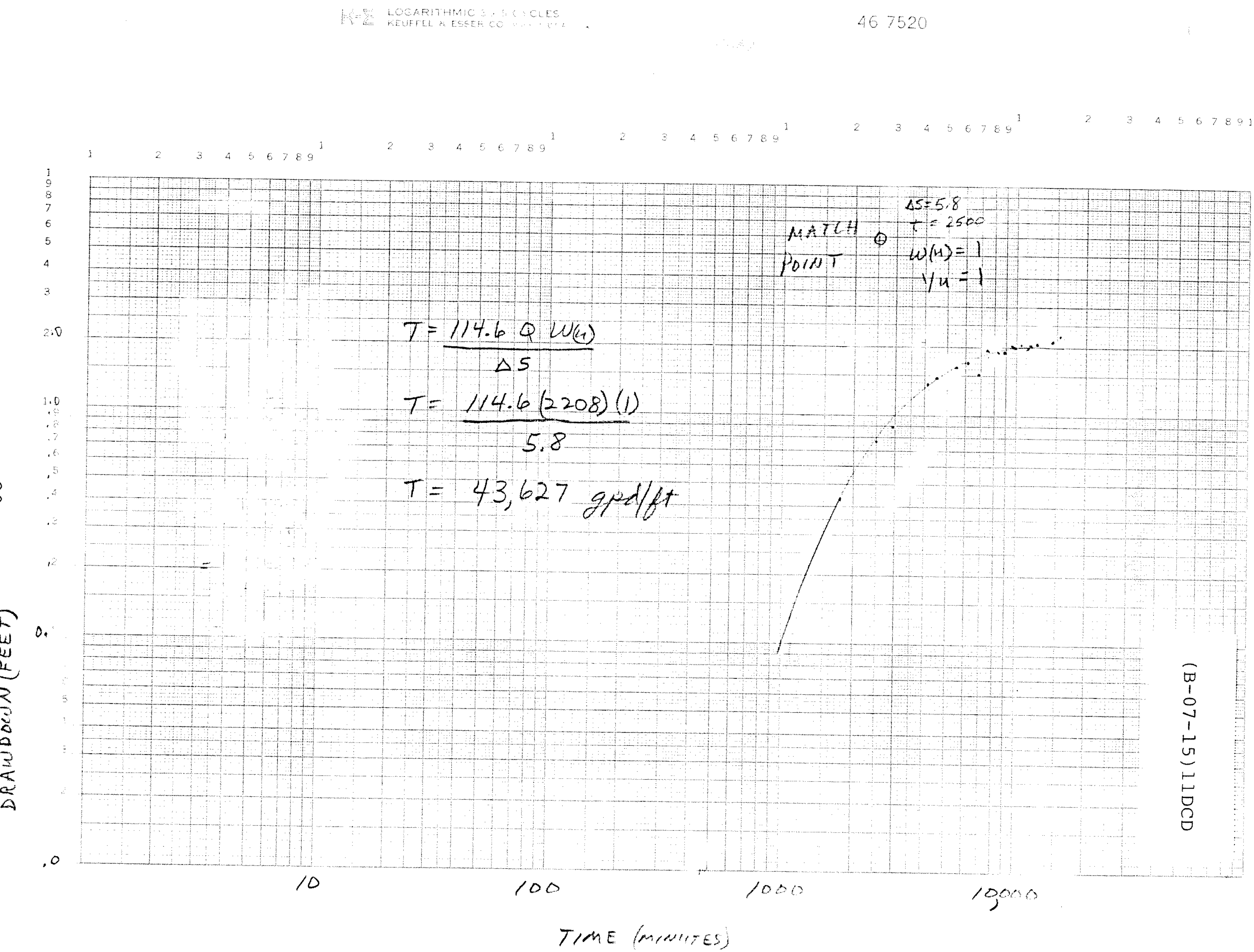


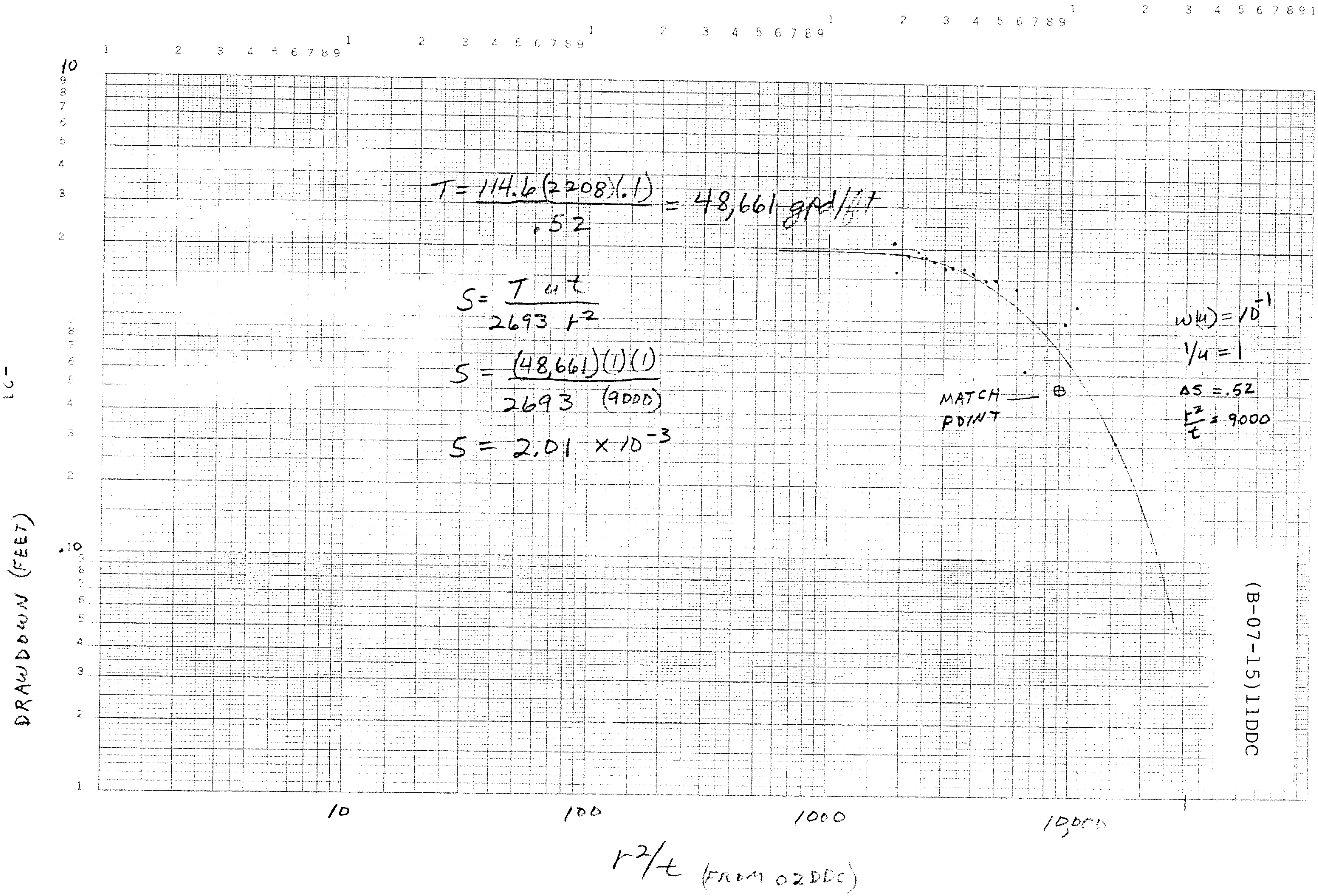
(B-07-15)02DDC
DISCHARGE EXTREMELY VARIABLE
PUMP AT (B-07-15)15AAD1 TURNED ON
ΔS = 12.5
t_0 = .027
T = 264 (Q) / ΔS
T = 264 (2208) / 12.5 = 46,632 gpd/ft
t
DRAWDOWN (FEET)
70
80
90
100
110
120
130
1.0
10
100
1000
10,000
DIETZGEN CORPORATION
MADE IN U.S.A.
NO. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH

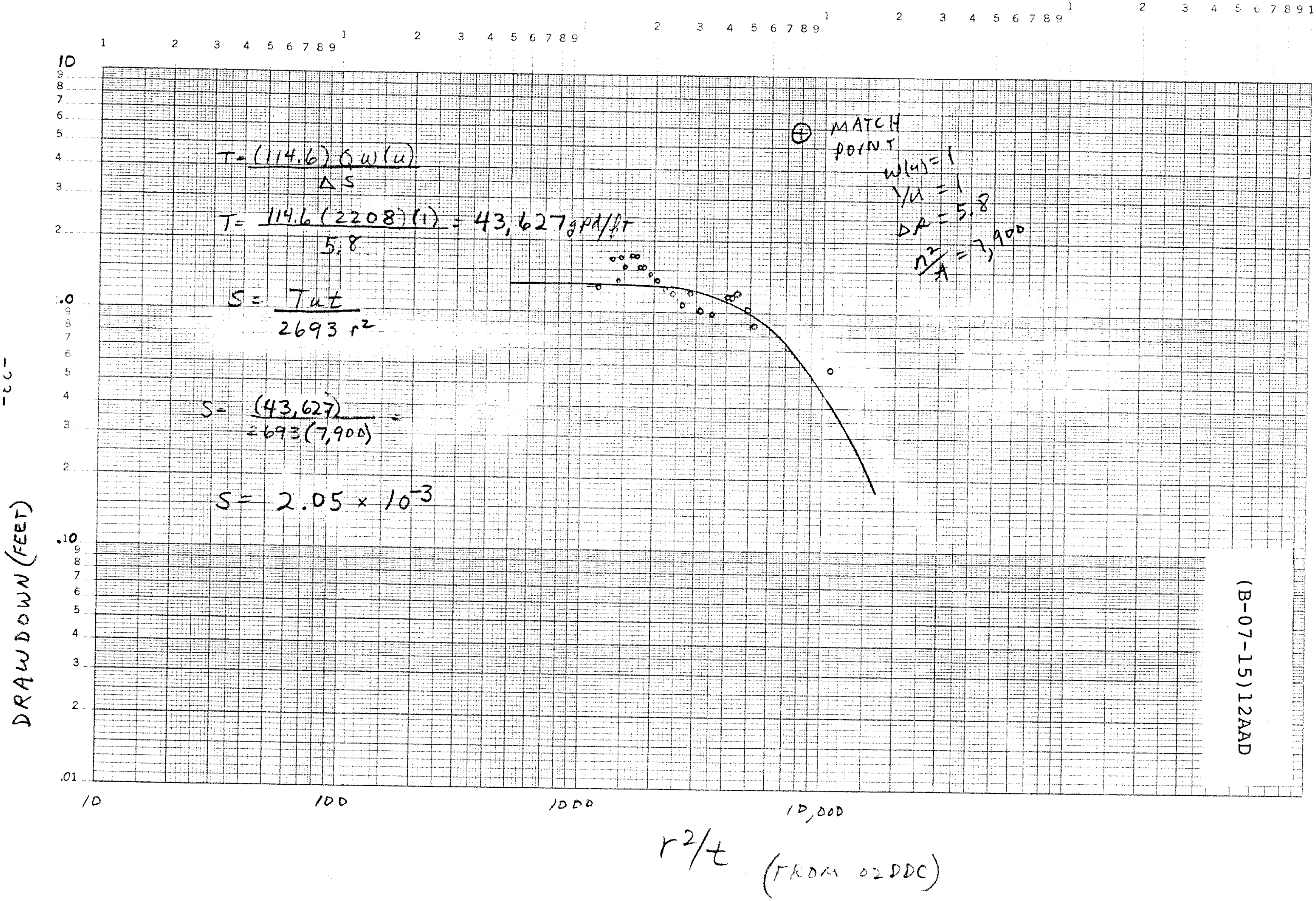

(B-07-15)02DDC
0.1 CURVE
$T = \frac{114.6\ Q\ W(u)}{\Delta s}$
$T = \frac{114.6\ (2208)\ (1)}{6.3} = 40,165\ gpd/ft$
MATCH POINT
W(u) = 1.0
1/u = 10^6
DRAWDOWN (FEET)
t_{2DDC} (MINUTES)
1.0
10
100
1000
10,000
200
100
10
1

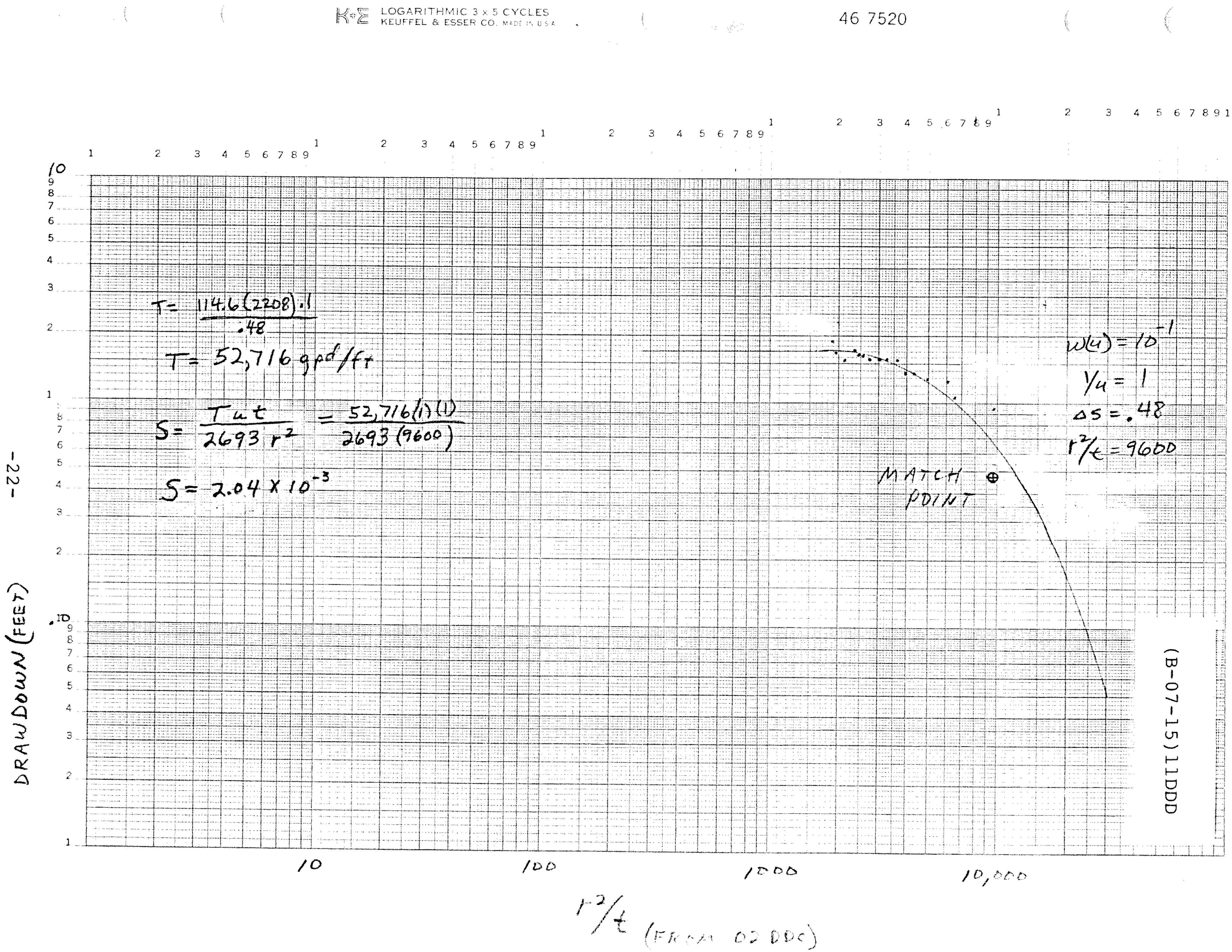

(B-07-15)02DDC
T = 264 Q / ΔS
T = 264 (2208) / 10.7
T = 54,478 gpd/ft
ΔS = 10.7
RATIO t/t'
100
1000
10,000
5
10
15
20
25
30
RESIDUAL DRAWDOWN (FEET)

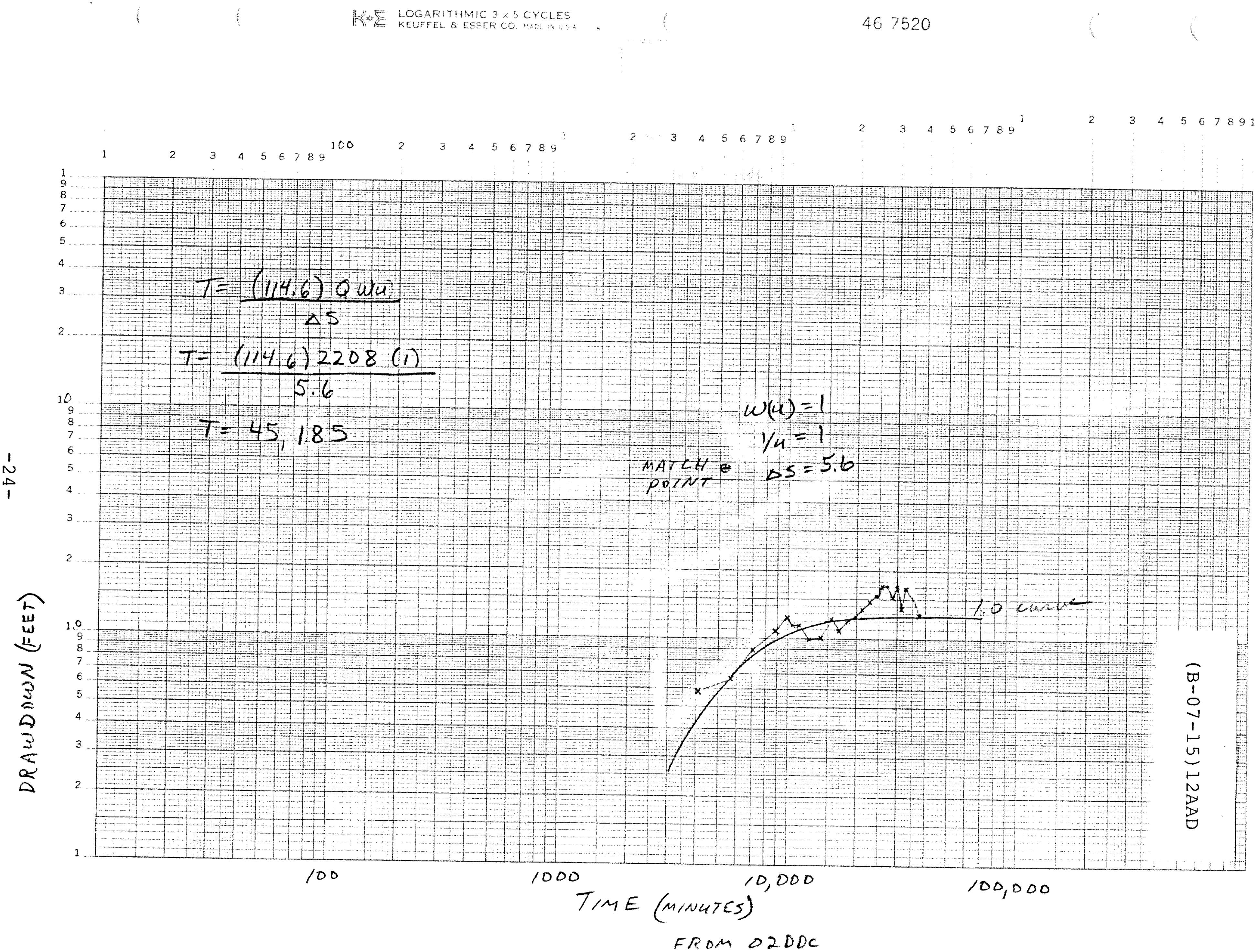

(B-07-15)11DCD
T = (114.6) Q W(u) / ΔS
= 114.6 (2208)(.1) / .58
T = 43,627 gpd/ft
S = Tut / 2693 r²
= (43,627)(1) / 2693 (10,500)
S = 1.54 x 10⁻³
W(u) = 10⁻¹
1/u = 1
ΔS = .58
r²/t = 10,500
match point
DRAWDOWN (FEET)
r²/t (FROM 02DDC)
10
100
1000
10,000

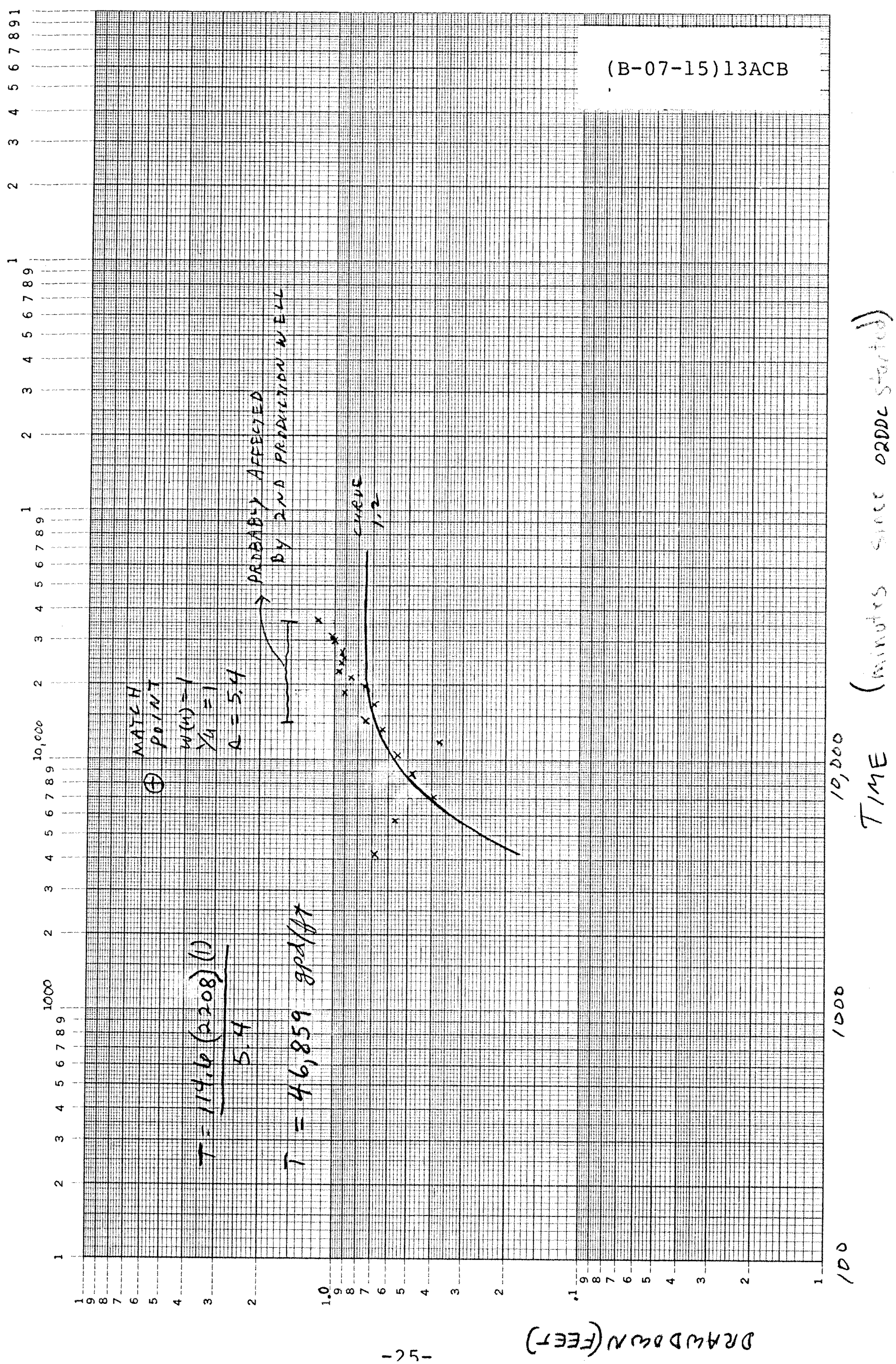

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO.
46 7520
(B-07-15)11DCD
MATCH POINT
ΔS=5.8
T = 2500
W(u) = 1
1/u = 1
T = 114.6 Q W(u) / ΔS
T = 114.6 (2208) (1) / 5.8
T = 43,627 gpd/ft
DRAWDOWN (FEET)
TIME (MINUTES)
10
100
1000
10,000

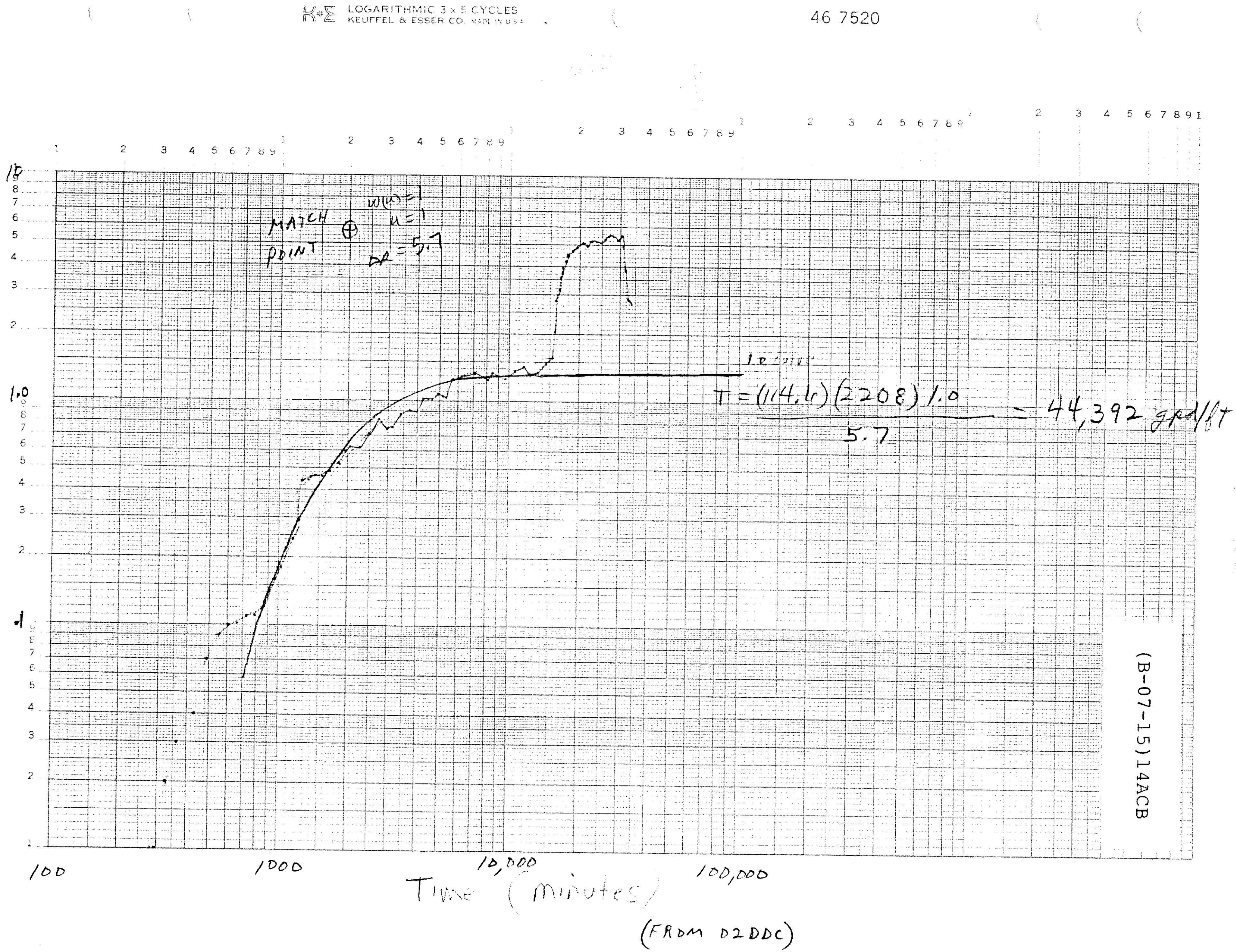

(B-07-15)11DDC
$T = \frac{114.6(2208)(.1)}{.52} = 48,661$ gpd/ft
$S = \frac{T\,u\,t}{2693\,r^2}$
$S = \frac{(48,661)(1)(1)}{2693\,(9000)}$
$S = 2.01 \times 10^{-3}$
$W(u) = 10^{-1}$
$1/u = 1$
$\Delta s = .52$
$r^2/t = 9000$
MATCH POINT
DRAWDOWN (FEET)
r^2/t (FROM 02DDC)
10
100
1000
10,000

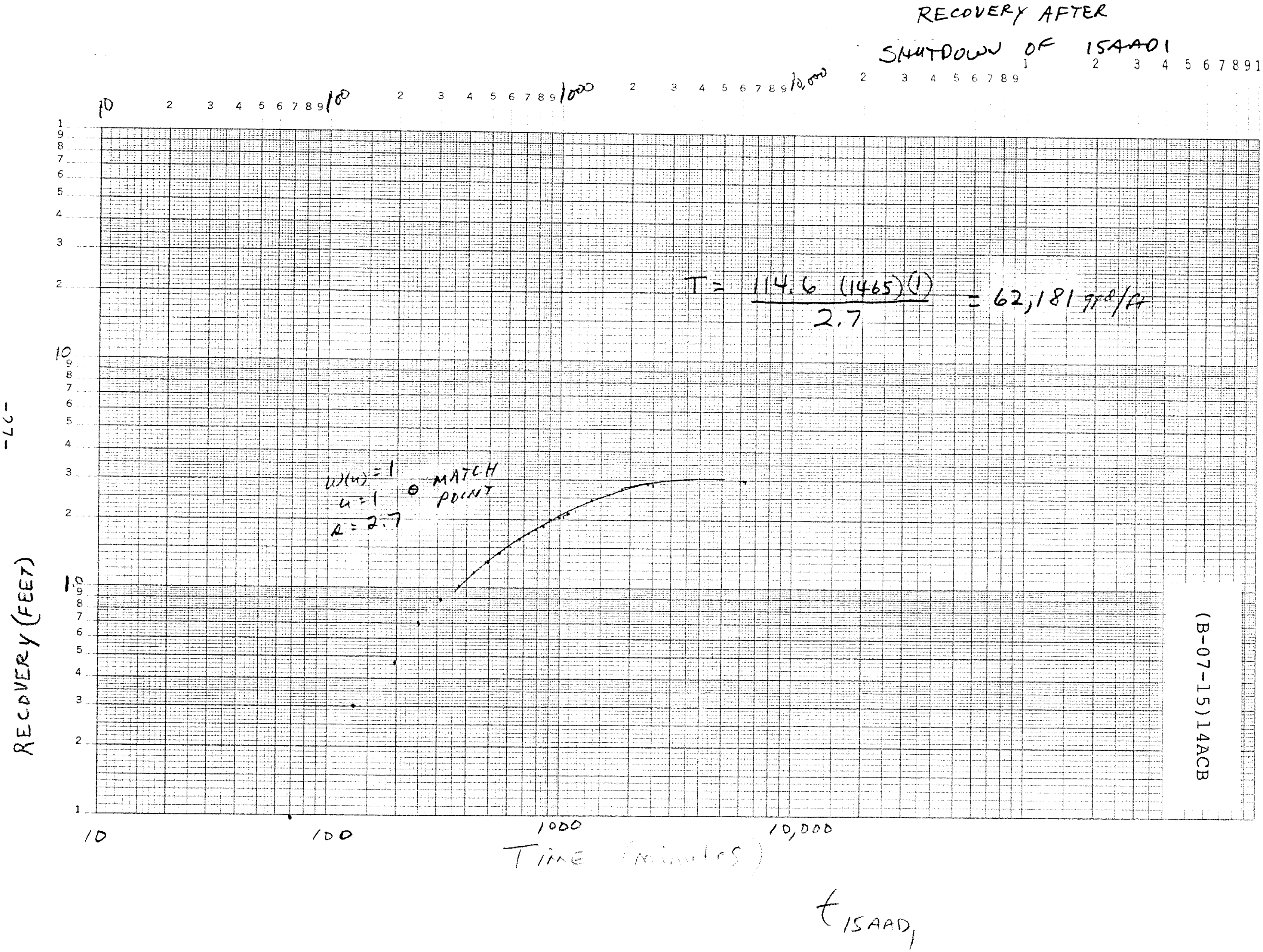

T = (114.6) Q w(u) / Δs
T = 114.6 (2208)(1) / 5.8 = 43,627 gpd/ft
S = T u t / 2693 r²
S = (43,627) / 2693(7,900) =
S = 2.05 × 10⁻³
MATCH POINT
w(u) = 1
1/u = 1
Δs = 5.8
r²/t = 7,900
DRAWDOWN (FEET)
r²/t (FROM 02DDC)
(B-07-15)12AAD
10
100
1000
10,000
.01
.10
1.0
10

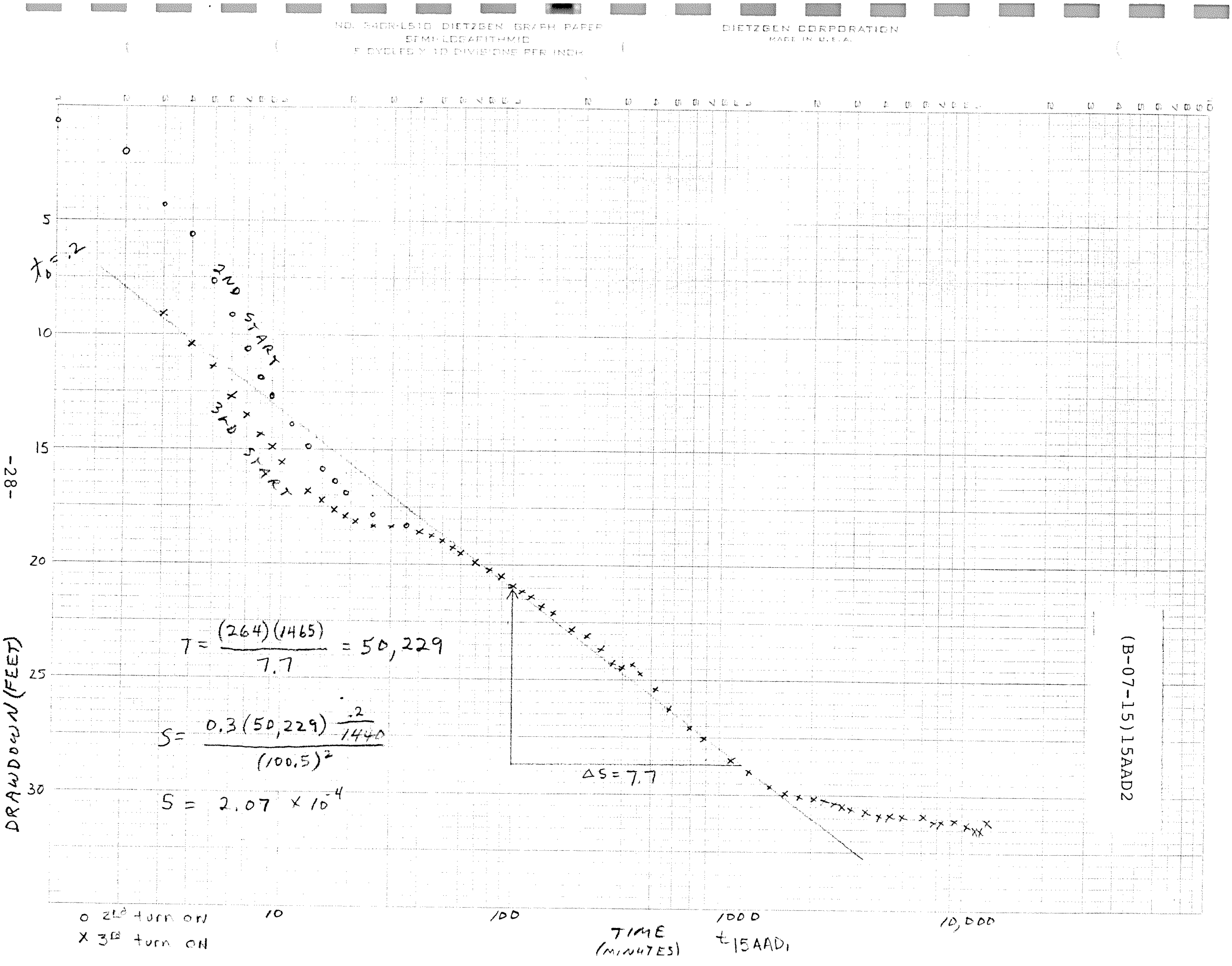

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7520
DRAWDOWN (FEET)
$T = \frac{114.6(2208)(.1)}{.48}$
T = 52,716 gpd/ft
$S = \frac{Tut}{2693 r^2} = \frac{52,716(1)(1)}{2693(9600)}$
$S = 2.04 \times 10^{-3}$
$W(u) = 10^{-1}$
$1/u = 1$
$\Delta s = .48$
$r^2/t = 9600$
MATCH POINT
10
100
1000
10,000
r^2/t (FROM 02DDC)
(B-07-15)11DDD

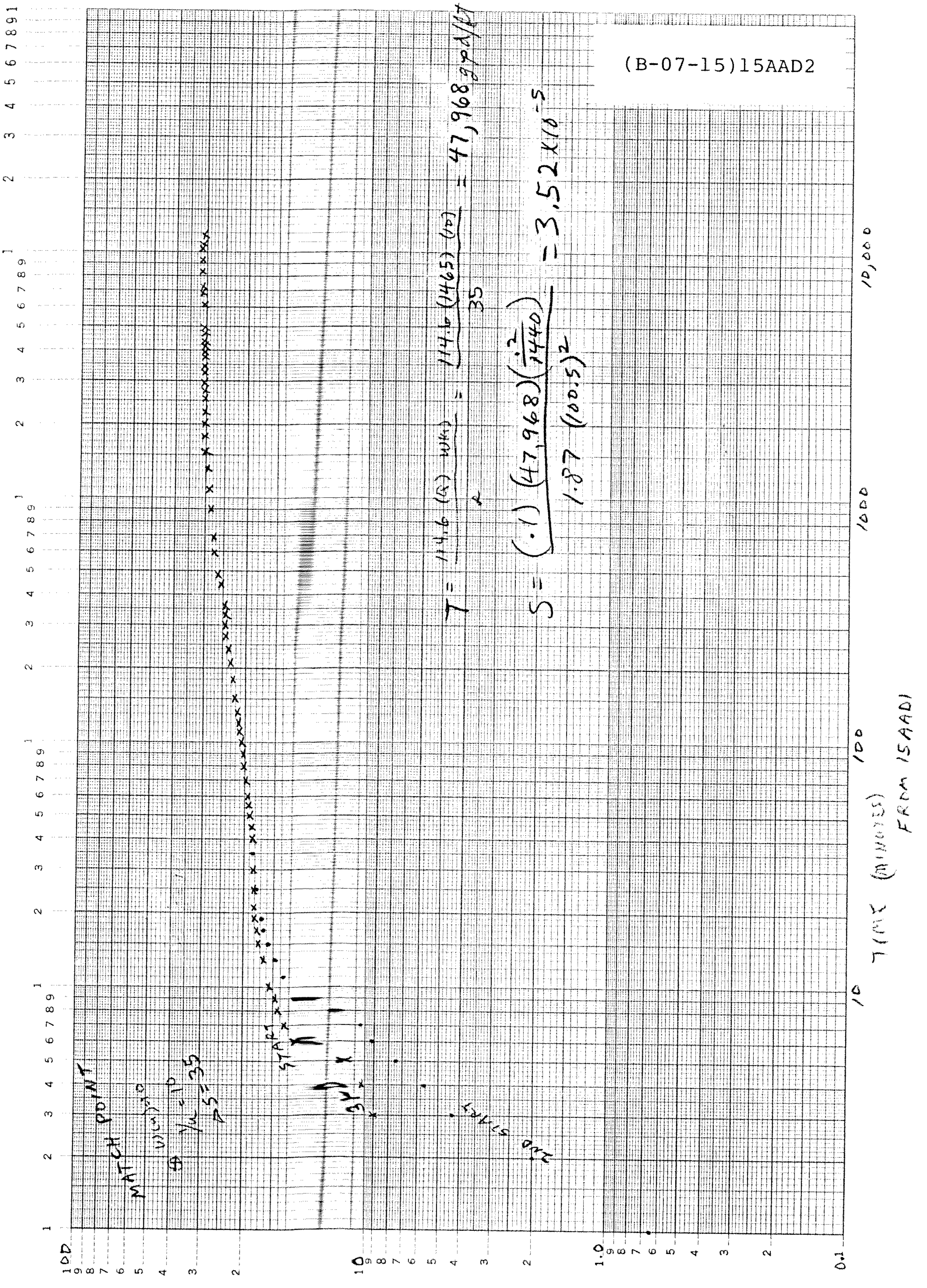

LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7520
T= (114.6) Q W(u) / ΔS
T= (114.6) 2208 (1) / 5.6
T= 45,185
W(u)=1
1/u=1
MATCH POINT ⊕ ΔS=5.6
1.0 curve
(B-07-15)12AAD
DRAWDOWN (FEET)
100
1000
10,000
100,000
TIME (MINUTES)
FROM D2DDC

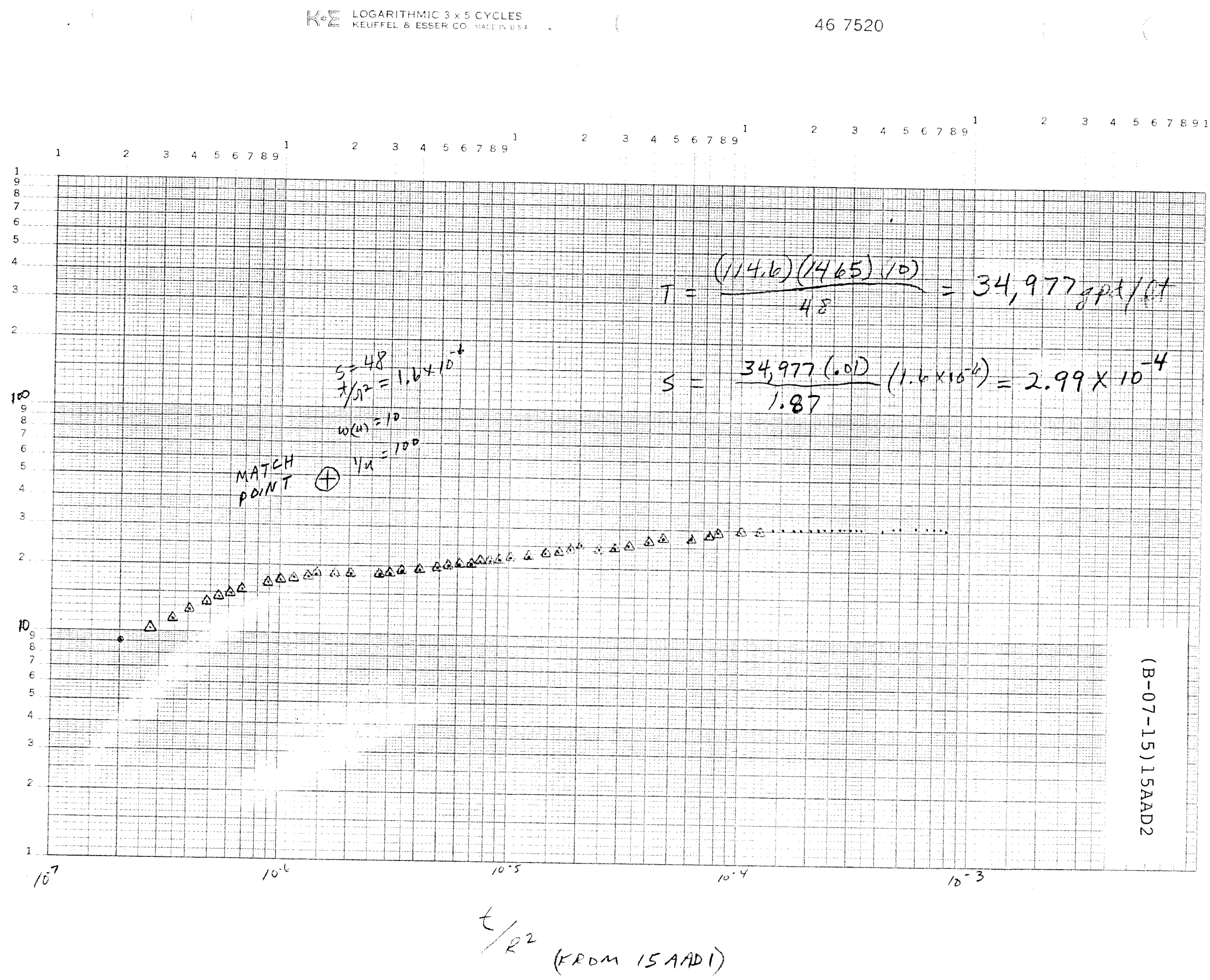

(B-07-15)13ACB
MATCH POINT
W(u) = 1
1/u = 1
s = 5.4
T = 114.6 (2208) (1) / 5.4
T = 46,859 gpd/ft
PROBABLY AFFECTED BY 2ND PRODUCTION WELL
CURVE 1.2
TIME (minutes since 02DDC started)
DRAWDOWN (FEET)
100
1000
10,000


LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7520
(B-07-15)14ACB
MATCH POINT
W(u) = 1
u = 1
Δh = 5.7
1.0 curve
T = (114.6)(2208) 1.0 / 5.7 = 44,392 gpd/ft
DRAWDOWN (FEET)
Time (minutes)
100
1000
10,000
100,000
(FROM D2DDC)

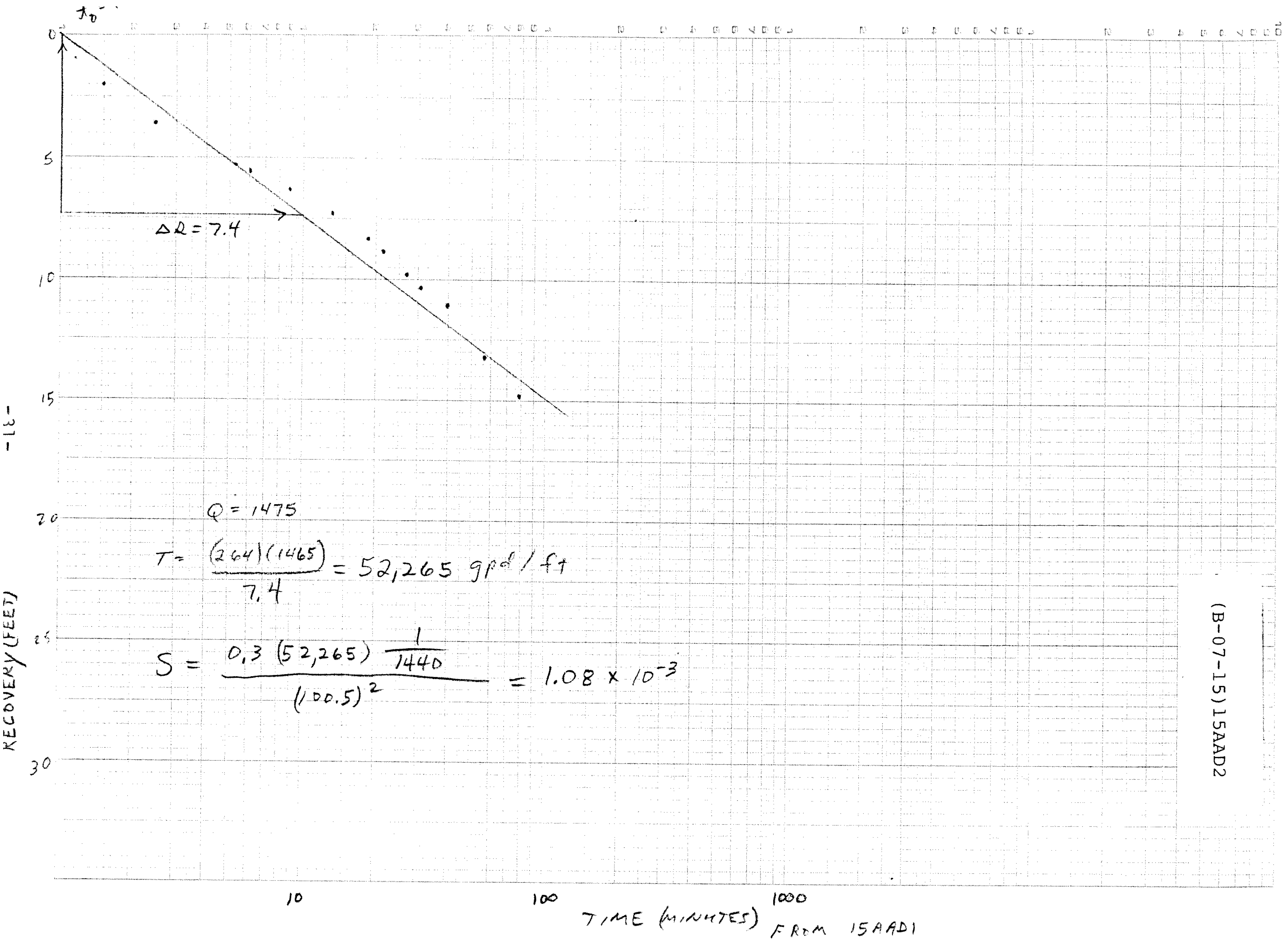

RECOVERY AFTER
SHUTDOWN OF 15AAD1
T = 114.6 (1465)(1) / 2.7 = 62,181 gpd/ft
W(u) = 1
u = 1
s = 2.7
MATCH POINT
(B-07-15)14ACB
RECOVERY (FEET)
10
100
1000
10,000
TIME (minutes)
t 15AAD1

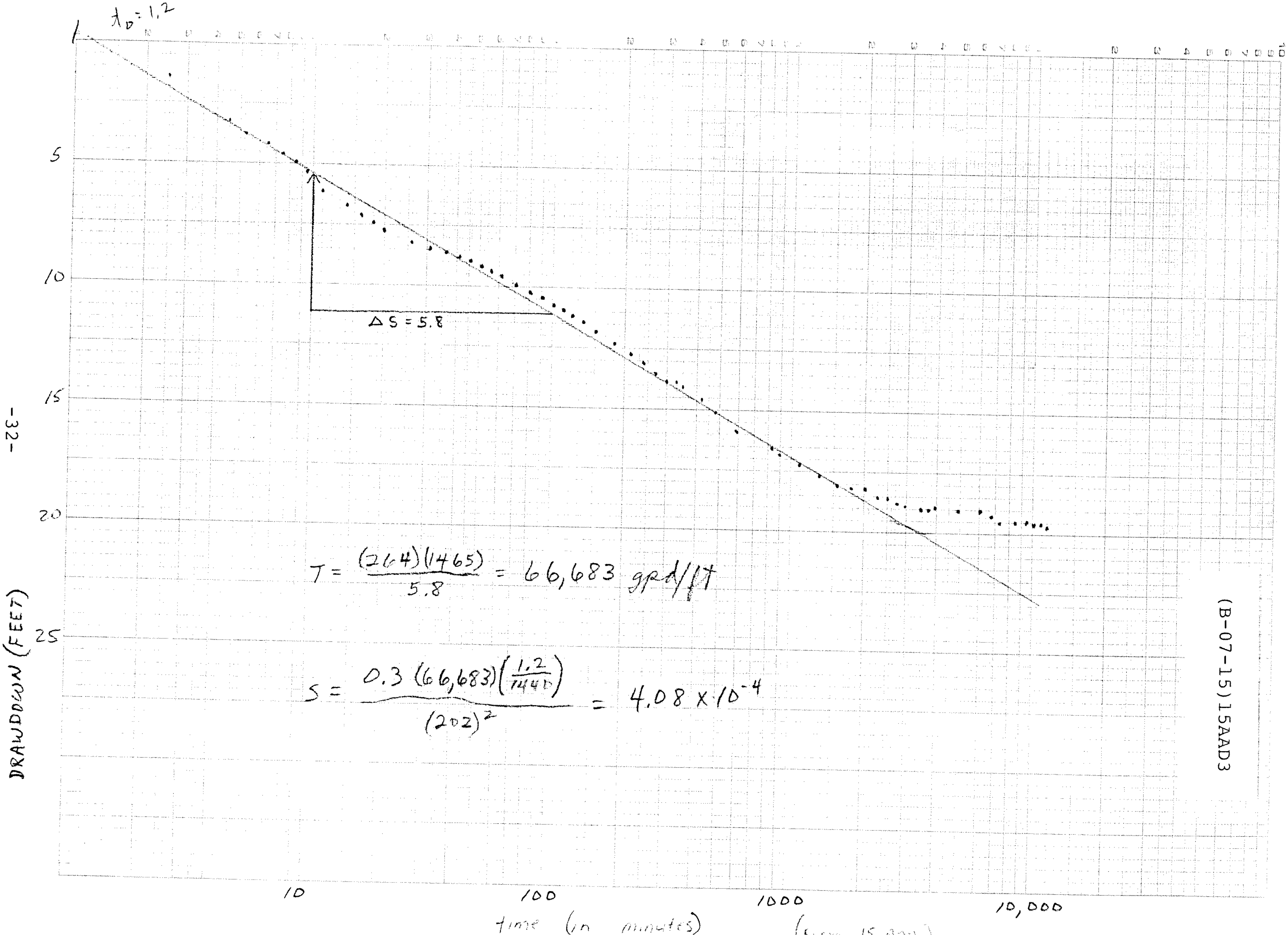

NO. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.
(B-07-15)15AAD2
$t_0 = .2$
2ND START
3RD START
$T = \frac{(264)(1465)}{7.7} = 50,229$
$S = \frac{0.3(50,229)\frac{.2}{1440}}{(100.5)^2}$
$S = 2.07 \times 10^{-4}$
$\Delta s = 7.7$
o 2nd turn on
X 3rd turn ON
DRAWDOWN (FEET)
TIME (MINUTES)
t 15AAD1
10
100
1000
10,000
5
10
15
20
25
30


(B-07-15)15AAD2
MATCH POINT
W(u) = 1.0
1/u = 10
s = 35
START
3RD
2ND START
T = 114.6 (Q) W(u) / s = 114.6 (1465) (1.0) / 35 = 47,968 gpd/ft
S = (.1) (47,968) (2/1440) / 1.87 (100.5)² = 3.52x10⁻⁵
TIME (MINUTES) FROM 15AAD1
DRAWDOWN (FEET)



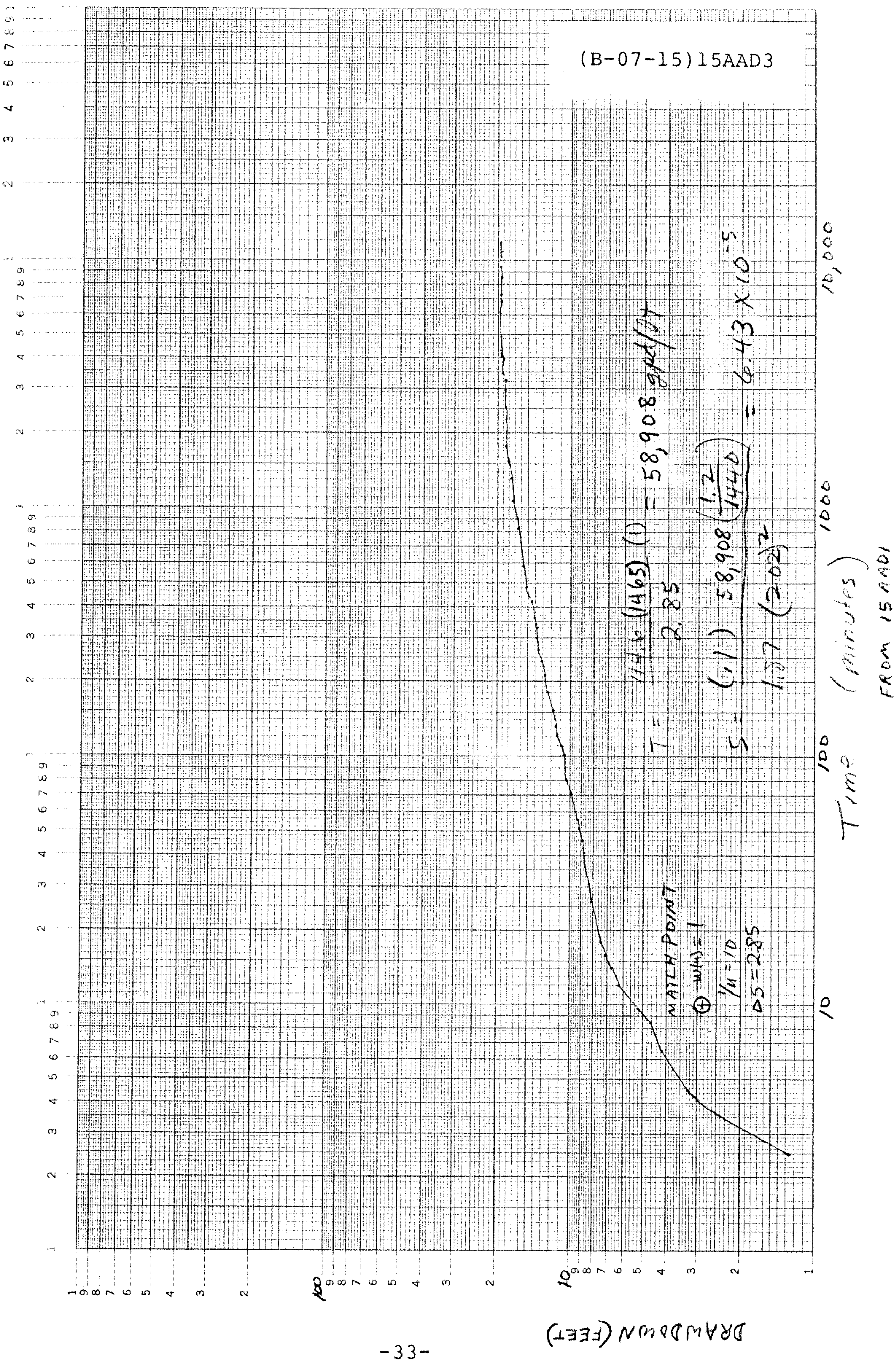
LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7520
(B-07-15)15AAD2
T = (114.6)(1465)(10) / 48 = 34,977 gpd/ft
S = 34,977 (.01) / 1.87 (1.6×10⁻⁶) = 2.99 X 10⁻⁴
s = 48
t/r² = 1.6×10⁻⁶
W(u) = 10
1/u = 100
MATCH POINT
DRAWDOWN (FEET)
t/r² (FROM 15AAD1)
10⁻⁷
10⁻⁶
10⁻⁵
10⁻⁴
10⁻³

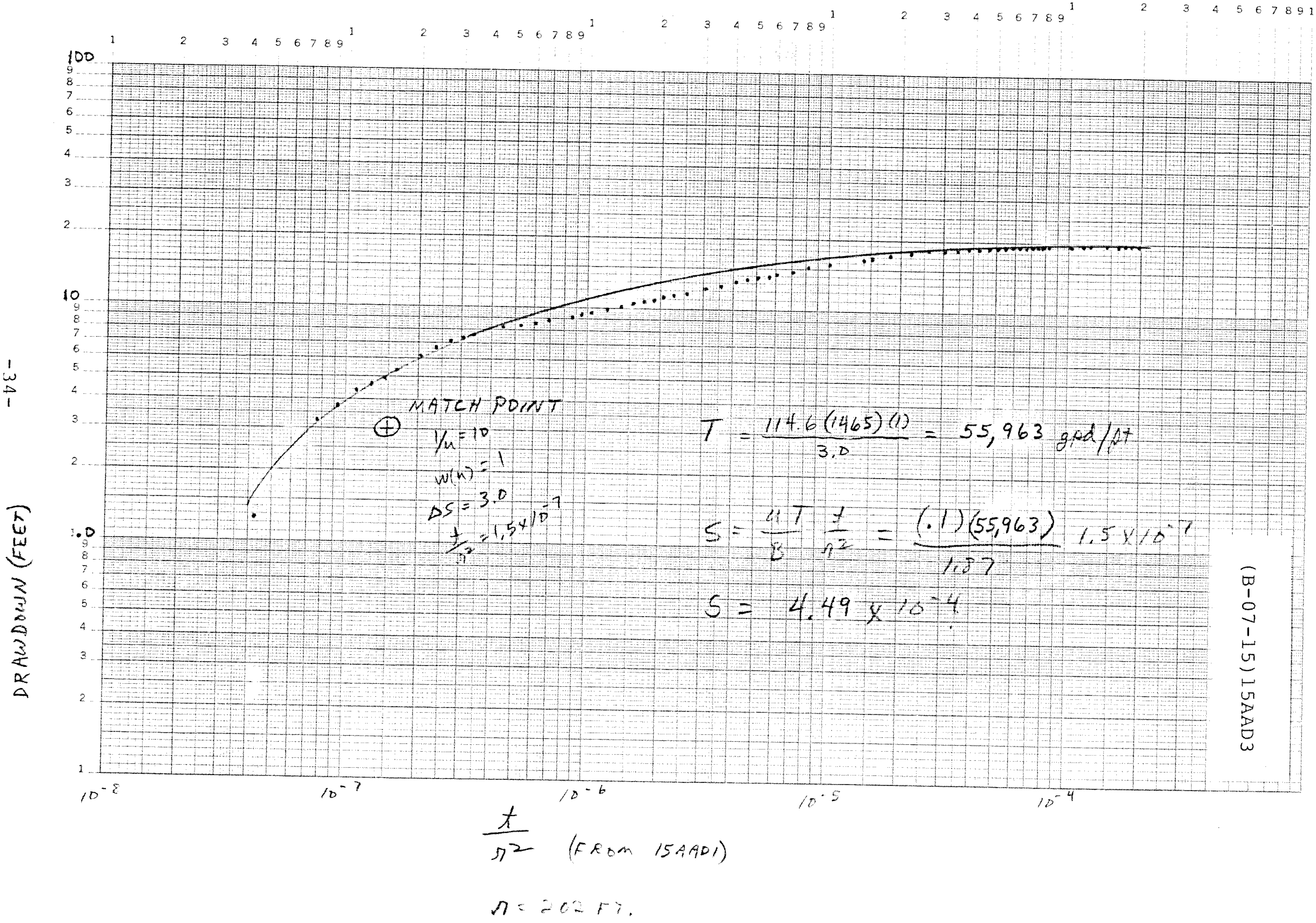

(B-07-15)15AAD2
t_0
$\Delta R = 7.4$
Q = 1475
$T = \frac{(264)(1465)}{7.4} = 52{,}265$ gpd/ft
$S = \frac{0.3\,(52{,}265)\,\frac{1}{1440}}{(100.5)^2} = 1.08 \times 10^{-3}$
0
5
10
15
20
25
30
RECOVERY (FEET)
10
100
1000
TIME (MINUTES) FROM 15AAD1



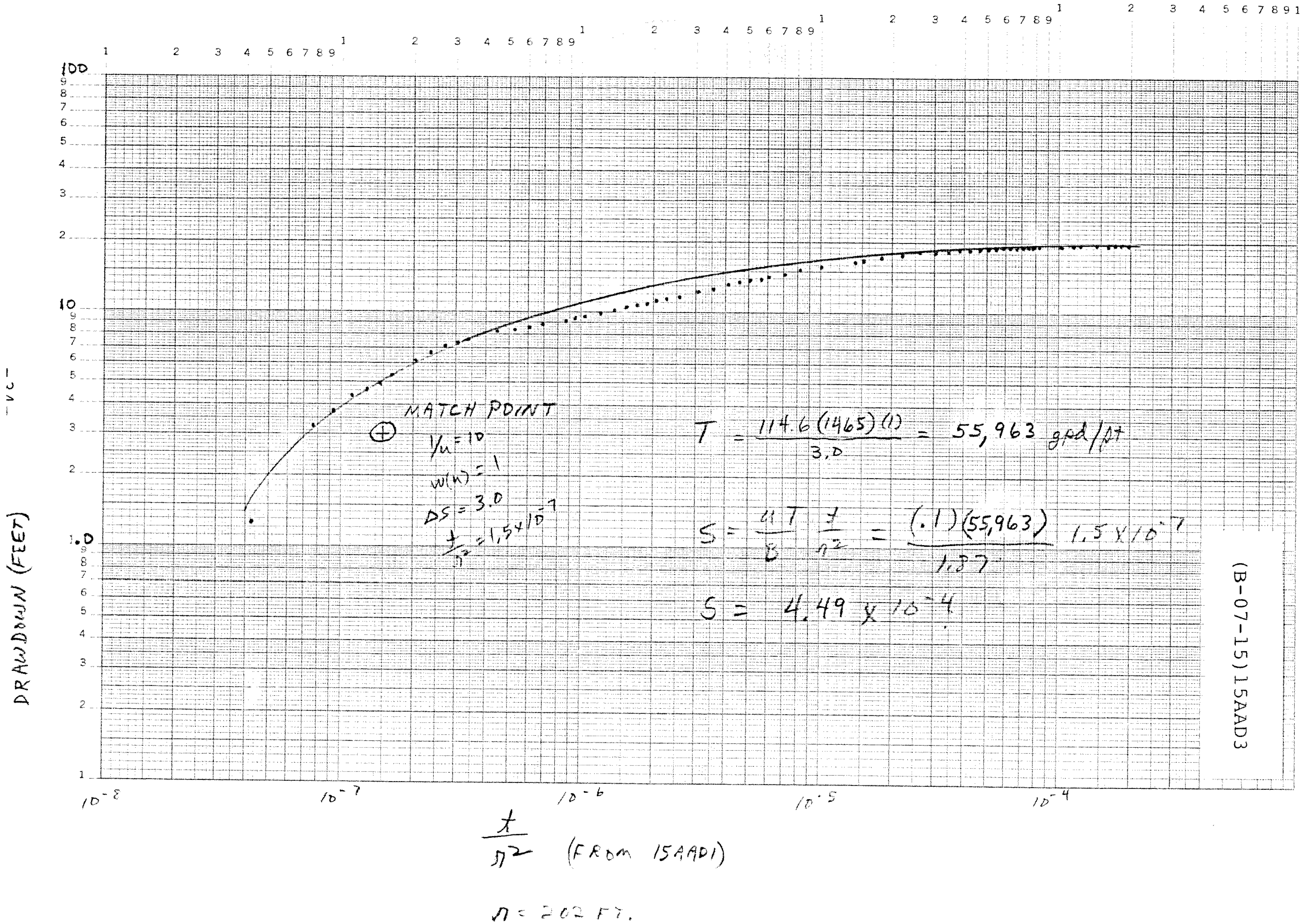
$$T = \frac{(264)(1465)}{5.8} = 66,683 \text{ gpd/ft}$$

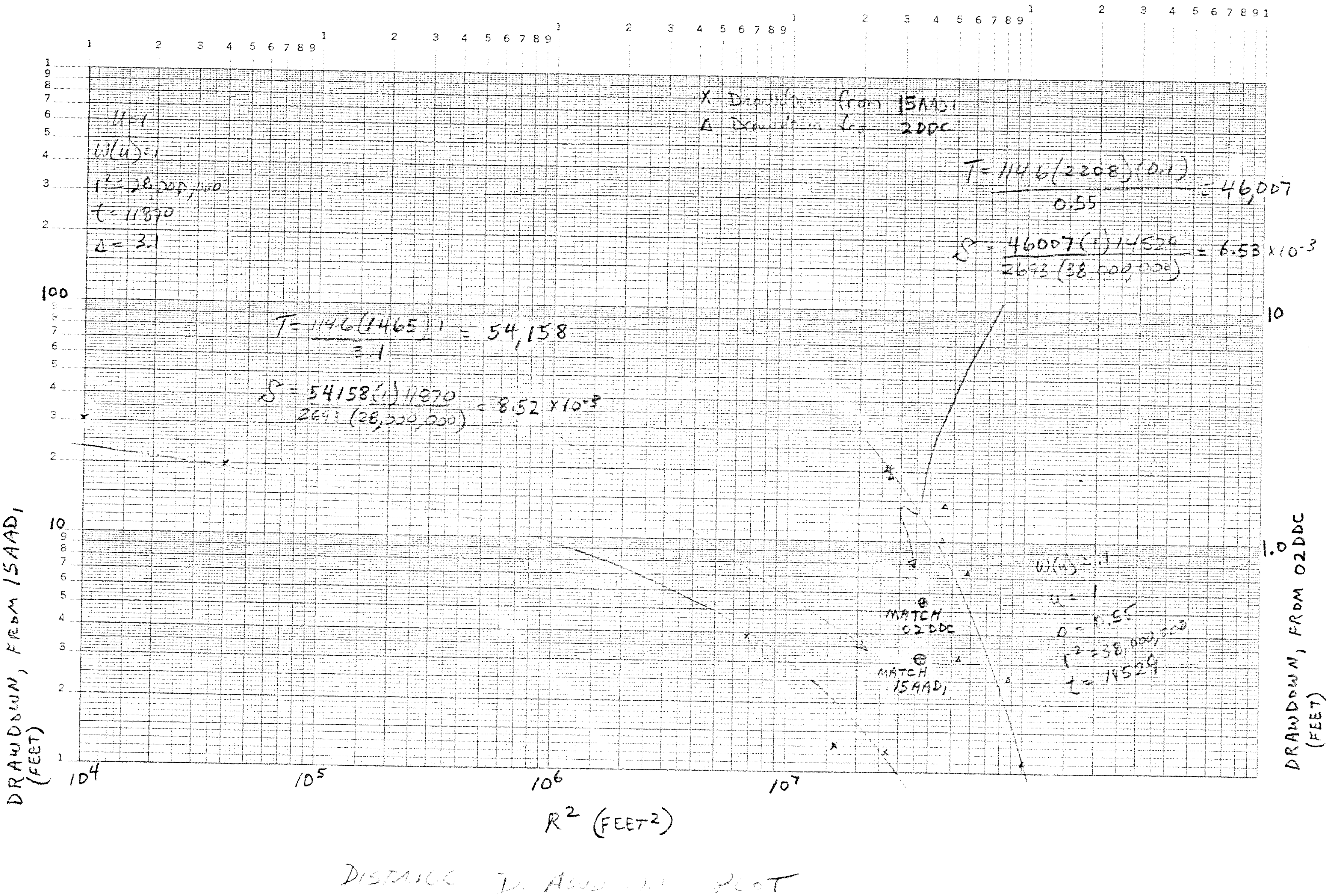
$$S = \frac{0.3\,(66,683)\left(\frac{1.2}{1440}\right)}{(202)^2} = 4.08 \times 10^{-4}$$


(B-07-15)15AAD3
T = 114.6 (1465) (1) / 2.85 = 58,908 gpd/ft
S = (.1) 58,908 (1.2/1440) / 1.87 (302)^2 = 6.43 X 10^-5
MATCH POINT
W(u) = 1
1/u = 10
Δs = 2.85
10
100
1000
10,000
Time (minutes)
FROM 15 AAD1
DRAWDOWN (FEET)


(B-07-15)15AAD3
DRAWDOWN (FEET)
MATCH POINT
1/u = 10
W(u) = 1
ΔS = 3.0
t/r² = 1.54 × 10⁻⁷
T = 114.6 (1465)(1) / 3.0 = 55,963 gpd/ft
S = 4T/B · t/r² = (.1)(55,963) / 1.87 · 1.5 × 10⁻⁷
S = 4.49 × 10⁻⁴
t/r² (FROM 15AAD1)
r = 202 FT.

K+E LOGARITHMIC 3 x 5 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 7520




X Drawdown from 15AAD1
Δ Drawdown from 2DDC
u = 1
W(u) = 1
r² = 28,000,000
t = 11870
Δ = 3.1
T = 114.6(1465)(1) / 3.1 = 54,158
S = 54158(1)11870 / 2693(28,000,000) = 8.52 x10⁻³
T = 114.6(2208)(0.1) / 0.55 = 46,007
S = 46007(1)14529 / 2693(38,000,000) = 6.53 x10⁻³
W(u) = .1
u = 1
D = 0.55
r² = 38,000,000
t = 14529
MATCH 02DDC
MATCH 15AAD1
10⁴
10⁵
10⁶
10⁷
R² (FEET²)
DRAWDOWN, FROM 15AAD1 (FEET)
DRAWDOWN, FROM 02DDC (FEET)