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SLUG TESTING IN HIGHLY-PERMEABLE AQUIFERS

by

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INTRODUCTION

Many of the important aquifers of the United States consist of unconsolidated alluvium lying in major river valleys. Protection of the water quality of these aquifers is a matter of highest concern to the communities which draw upon these units for their water supplies. Numerous landfills or industrial-waste disposal areas have been placed on top of alluvial aquifers. There is a critical need to better evaluate the threat that such sites pose to the water supplies of the neighboring communities. A key element of evaluation efforts is the prediction of contaminant movement in the subsurface, which in turn depends on the measurement of hydraulic conductivity. Many techniques are available for determining hydraulic conductivity. None are totally satisfactory. Slug testing is one widely used technique which is relatively easy and inexpensive to perform. However, in small 2" diameter wells in highly permeable alluvium, it is usually not extremely accurate because of the short times for data measurement and the small volumes of water introduced into the aquifer. The purpose of this paper is to discuss a system for slug testing that overcomes these problems.

SITE DESCRIPTION

The recently developed Geohydrologic Experimental and Monitoring Site (GEMS) of the Kansas Geological Survey (KGS) is the field area used for this work. This site is located northeast of the Lawrence Airport on land owned by the University of Kansas. The specific tract of land on which GEMS is located is the Robinson Tract of the Kansas Ecological Reserves. Shown on this slide is a sketch of the Robinson Tract indicating the two areas which comprise the research site. The work of this paper was performed in the area marked A. The next slide is a blow up of area A where we have three nests of piezometers. GEMS overlies approximately 70 feet of Kansas River valley alluvium. These recent unconsolidated sediments overlie and are adjacent to materials of Pleistocene and Pennsylvanian age. The alluvial facies assemblage at this site consists of approximately 35 feet of clay and silt overlying 35 feet of sand and gravel. The stratigraphy is a complex system of stream-channel sand and overbank deposits. Since mid-April of 1988, 17 wells have been drilled in the alluvium underlying this site using a hollow-stem auger. The next slide shows a schematic of a typical well nest. A nest consists of 2" wells completed at 10 foot intervals with screens of approximately 2.5 feet in length. These are the wells on which we have used the slug test apparatus described in the remainder of this presentation.

EQUIPMENT

Most of the commercially available packers for two inch wells have small feed-through tubes on the order of one-half inch diameter. For alluvial aquifers composed of coarse sand and gravel, such a pipe may be unduly restrictive causing excessive head loss and resulting in hydraulic conductivity determinations that are too low. The next series of slides shows a packer we have constructed that has a one inch feed-through pipe. For fitting down a two inch well that is about the maximum allowable feed-through diameter. An innovative feature of this packer is a rubber stopper used to seal the feed-through pipe while the well is prepared for the slug test by filling the casing above the packer with water. The rubber stopper is attached to pump rods which extend to the surface. Pulling up on the pump rods unseats the stopper and initiates the slug test. The stopper may be reseated by pushing down on the pump rods. In this way, several slug tests may be performed without removing the packer from the well or deflating it.

Another potential problem with running slug tests in two inch wells is the fact that the casing holds very little water. For example, 20 feet of 2 inch casing holds only 3.26 gallons of water. In many slug tests the water level is not raised this high. Therefore, the value of hydraulic conductivity must be extremely local and may be significantly affected by drilling and completion techniques. As shown in the next slide, we have designed an above-ground reservoir that holds about twenty gallons of water. It is constructed from an 8 foot length of 8 inch diameter PVC pipe. The reservoir mechanism consists of the PCV pipe and a metal tripod that allows convenient positioning over the well. The reservoir is connected to the well with a water-tight rubber slip connector.

Several pieces of support equipment are needed for efficient operation of the slug-test system. Since each slug test uses about twenty gallons of water, we need a sizeable tank for water storage, as shown in this slide. The tank holds about 425 gallons, allowing approximately twenty slug tests to be performed before refilling. A three-quarter horsepower jet pump is used for filling the tank and for filling the slug-test reservoir. A ten-foot ladder is necessary for attending the reservoir. We use a nitrogen bottle with a regulator for inflating the packer. The water levels in the reservoir are monitored with a pressure transducer having a 0-5 psi range. The slug test is initiated by a mechanical trigger that pulls up the pump rods unseating the rubber stopper and throwing a microswitch which starts data collection. The trigger mechanism in the up and down positions and the microswitch are shown in this series of slides.

The data acquisition component of the system consists of a portable AT compatible computer, an analog to digital conversion board in one of the slots of an expansion chassis, and a power supply for the pressure transducers. The A to D board has 16 channels for input analog data and has 16 digital I/O channels. Data collection can proceed at rates up to 2500 Hz; however, we usually use the .5-100 Hz range. This data collection frequency range gives us good definition of the slug-test response, while producing data files of reasonable length . The trigger signal from the microswitch is input through one of the digital I/O channels; data collection can be started and stopped by lowering and raising the handle of the trigger mechanism. A variable voltage power supply is used to power the pressure tranducers with 12 VDC.

RESULTS

We have run over forty slug tests with this equipment to date. A number of improvements in the system have been made over the current field season and we feel that the current configuration is an accurate and efficient system for the performance of slug tests. Typically, results are reproducible at a given well within 1-3%. The current system gives a high density of data with good definition of the response, even at early times. We have developed a computer-automated least squares analysis of the slug-test data, which makes handling of the high data volume relatively easy. The next slide shows a typical plot of head data versus time, illustrating the plethora of data we are able to collect. The next three slides show the Hvorslev Analysis of the data for wells screened for 2.5 feet at depths of 45, 55, and 65 feet. As you can see there is a very good fit, and the hydraulic conductivity does vary with vertical position within the aquifer. It is a bit surprising that the hydraulic conductivity at 65 feet is lower than at 45 and 55 feet, since one might suppose that we have a fining upward sequence. However, preliminary grain-size analyses in this area indicates no such simple picture exists. We will be performing slug tests at much smaller vertical intervals later and expect to see a great deal of variation in the vertical direction.

SUMMARY

In summary, the system that we have described has great potential for improving the quality of the data and calculated results of any type of slug test. In particular, the system is suitable for use in two inch alluvial wells completed in coarse sand and gravel, where traditional slug-test methods may produce estimates of dubious value.

The major innovations of the system include: A two inch diameter packer with a one inch feed-through pipe and a rubber stopper, a large diameter above-ground reservoir holding about twenty gallons of water, an electronic trigger for delineating the start of the test, modern electronic data acquisition equipment for high data density, and an automated data analysis package for objective and efficient data handling. With this type of system we feel that the slug test can reach its full potential as a quantitative measure of the in situ hydraulic conductivity.

OUTLINE

- SITE DESCRIPTION
- SLUG-TEST SYSTEM
- TEST RESULTS

*G*eohydrologic

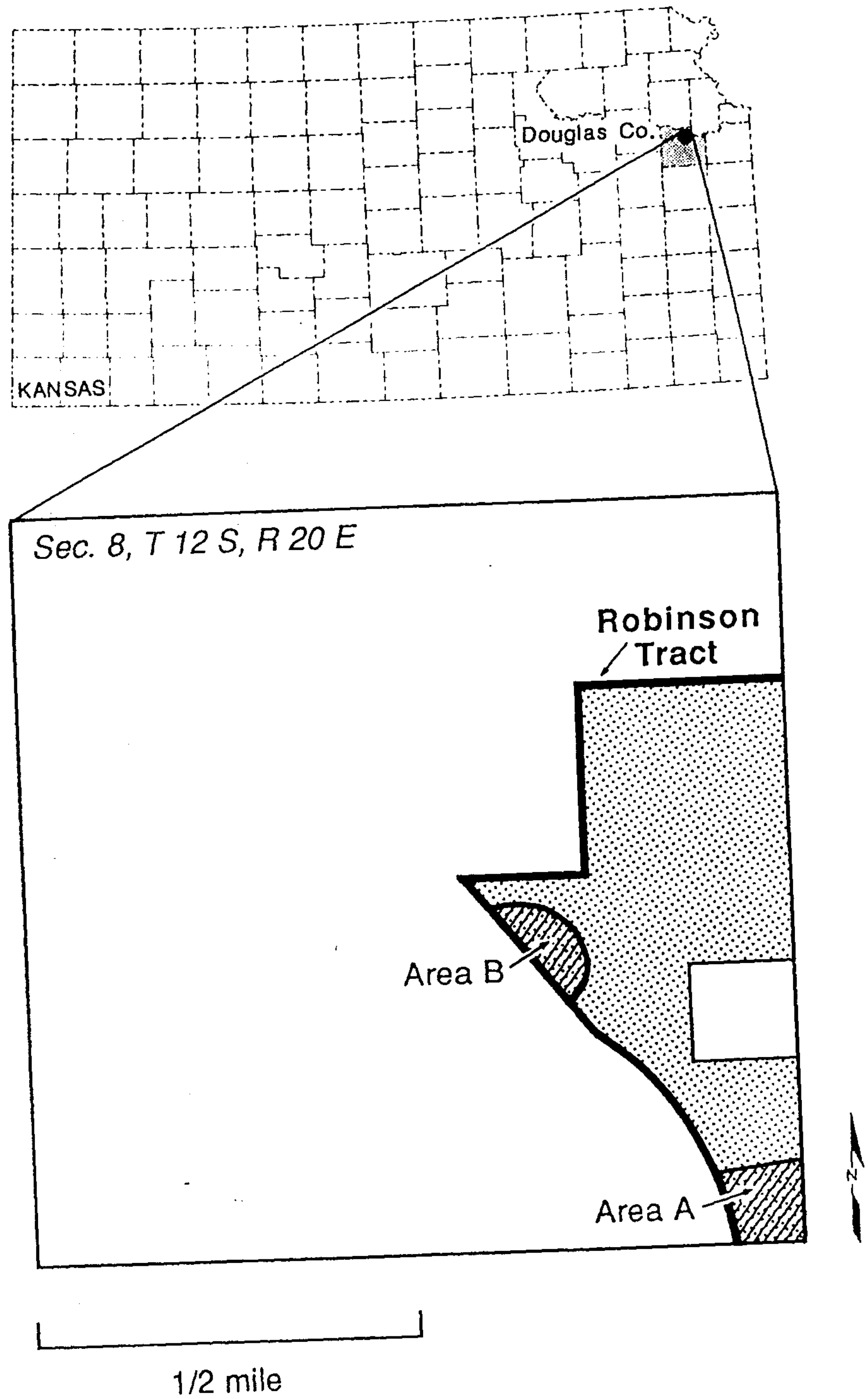
*E*xperimental

and

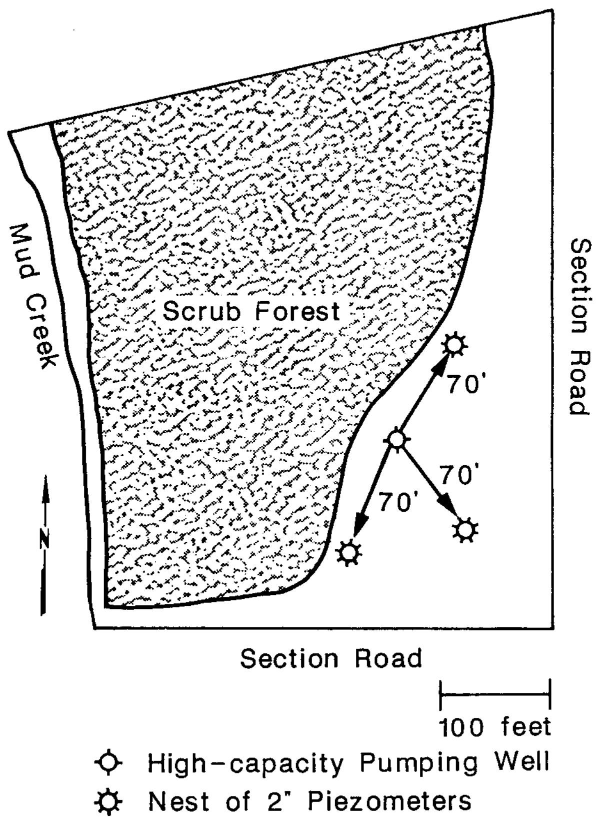
*M*onitoring

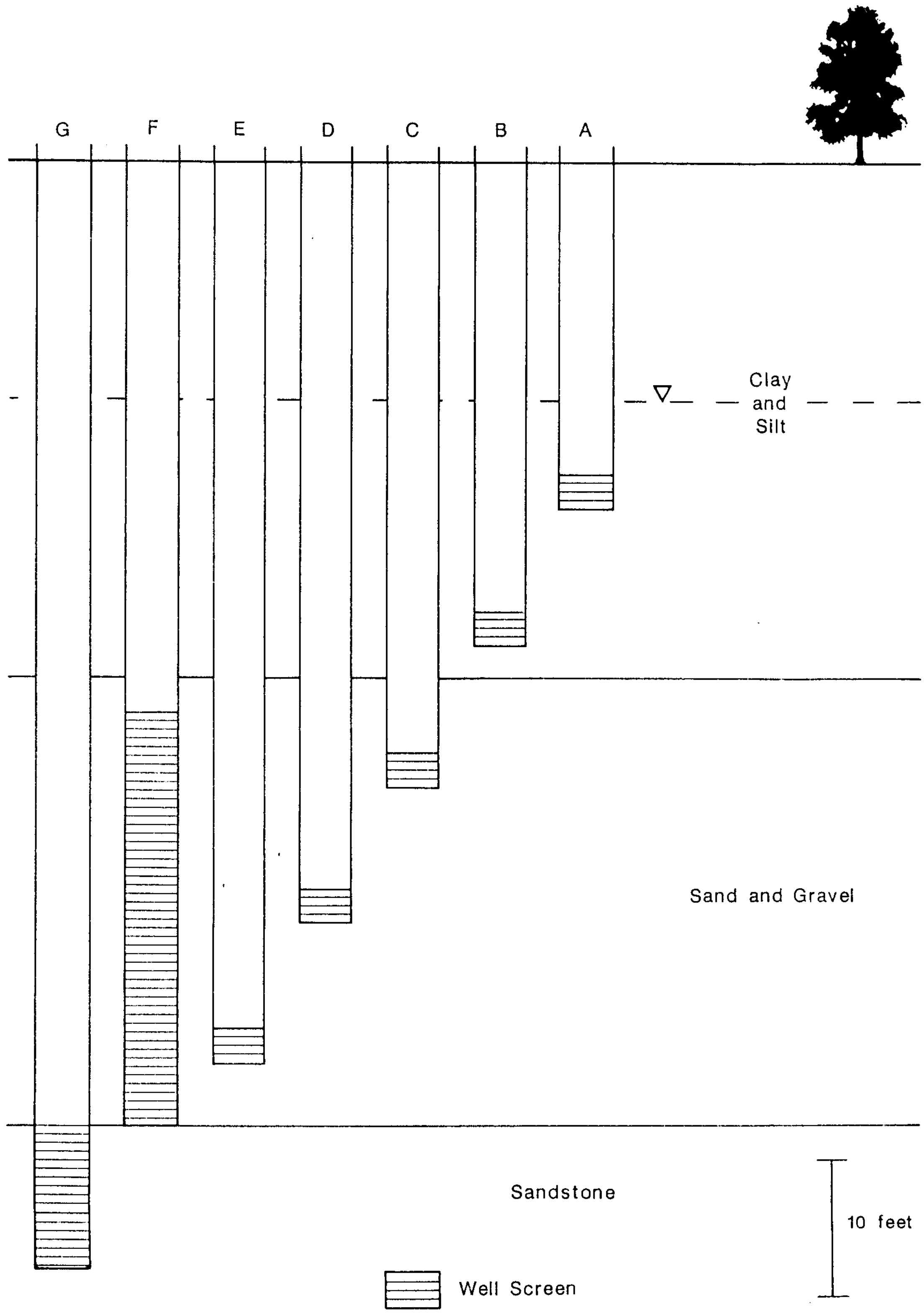
*S*ite


Kansas
Ecological
Reserves
Hunting And
Trespassing
Not
Permitted



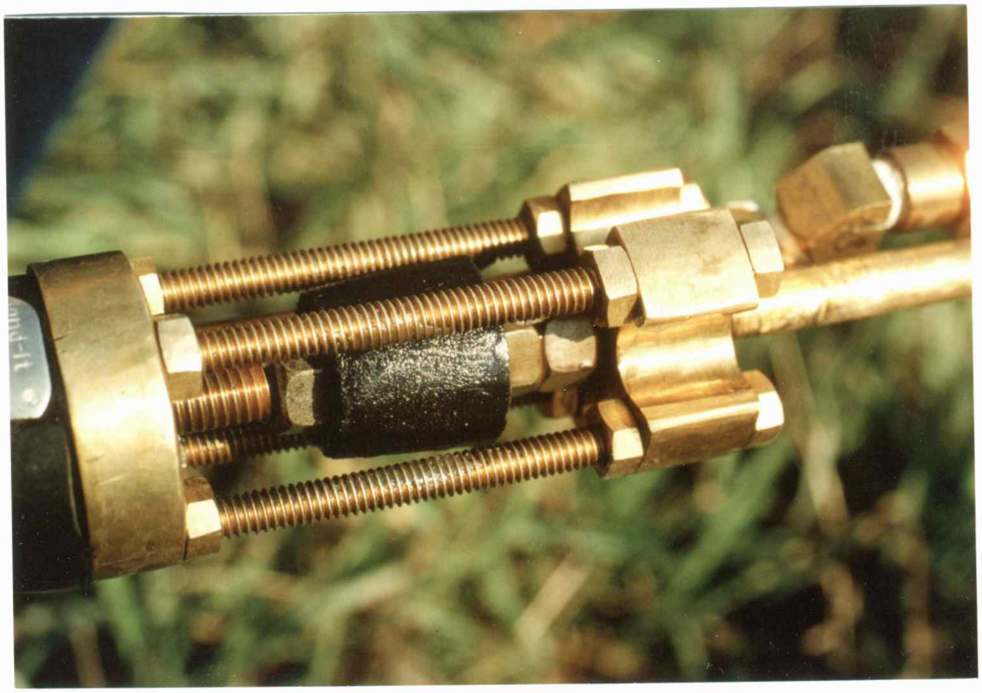
Douglas Co.
KANSAS
Sec. 8, T 12 S, R 20 E
Robinson Tract
Area B
Area A
N
1/2 mile


Scrub Forest
Mud Creek
Section Road
Section Road
70'
70'
70'
N
100 feet
High-capacity Pumping Well
Nest of 2" Piezometers

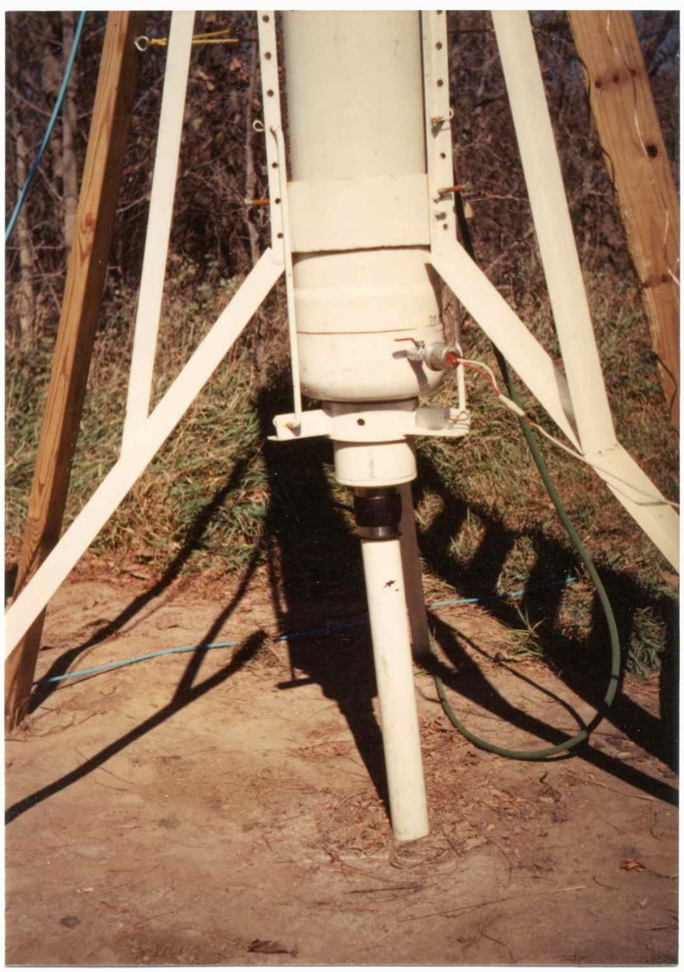


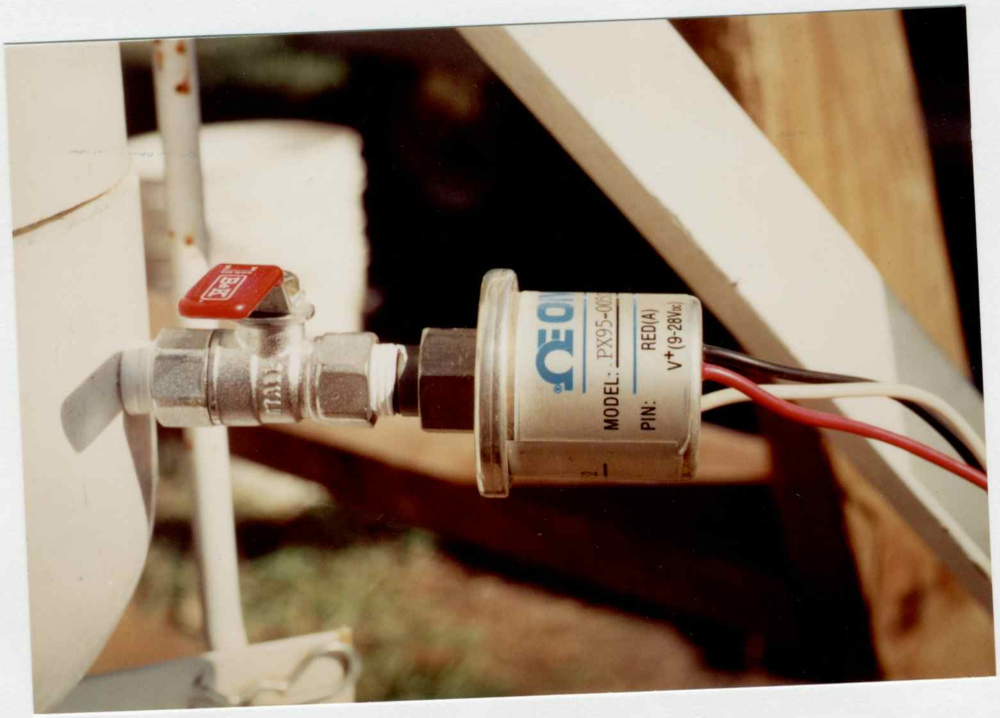
G
F
E
D
C
B
A
Clay and Silt
Sand and Gravel
Sandstone
10 feet
Well Screen


0 CM 5 10 15





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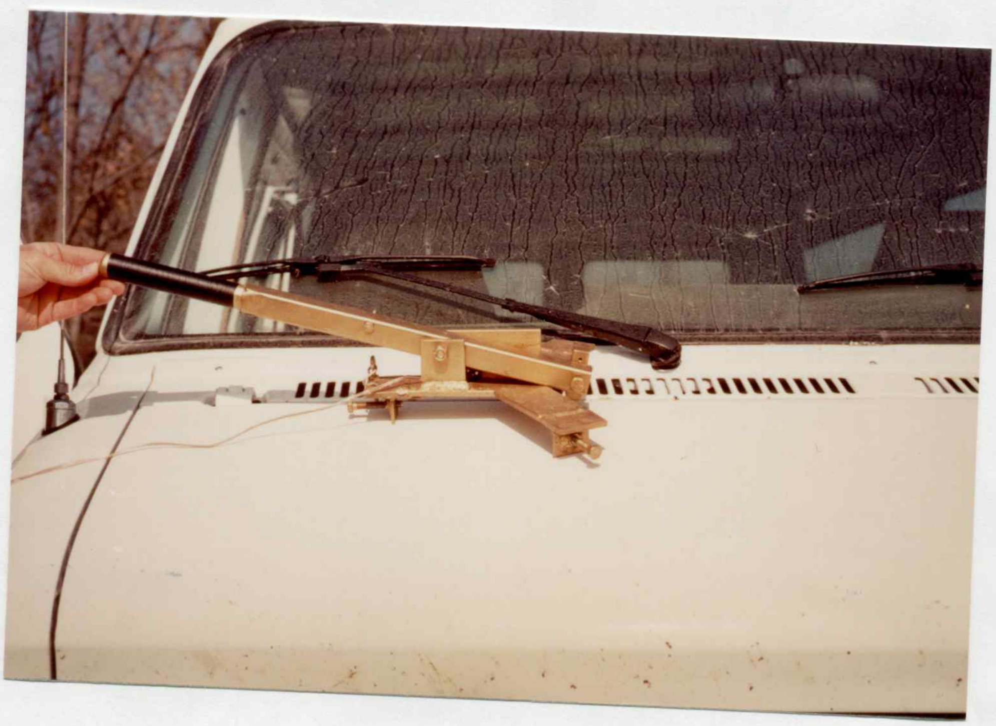
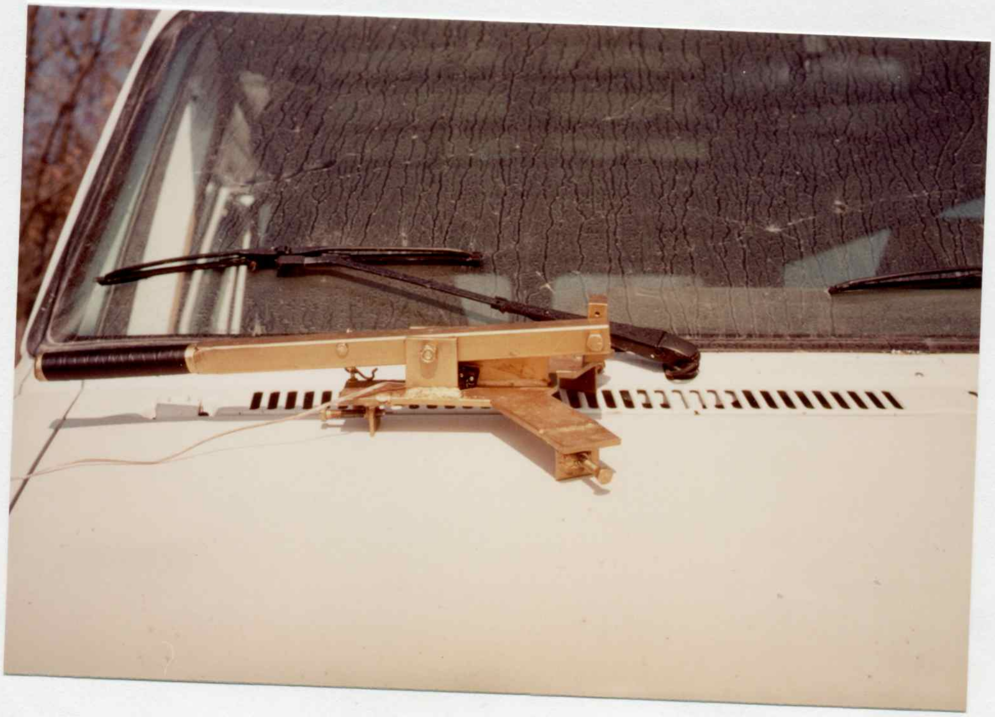
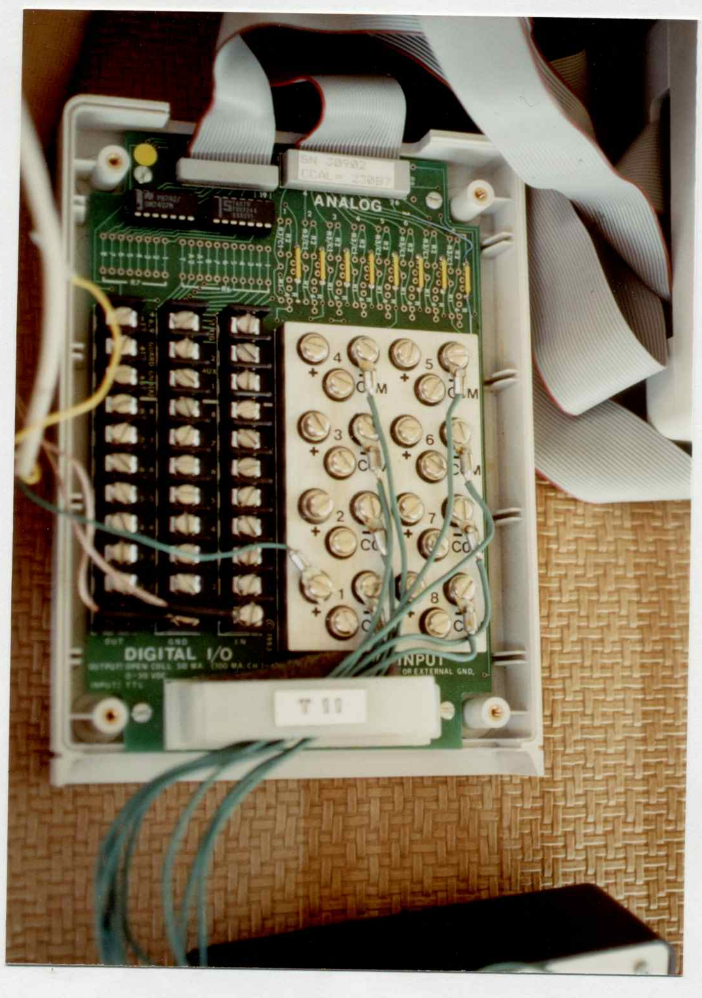
V+(9-28Vdc)

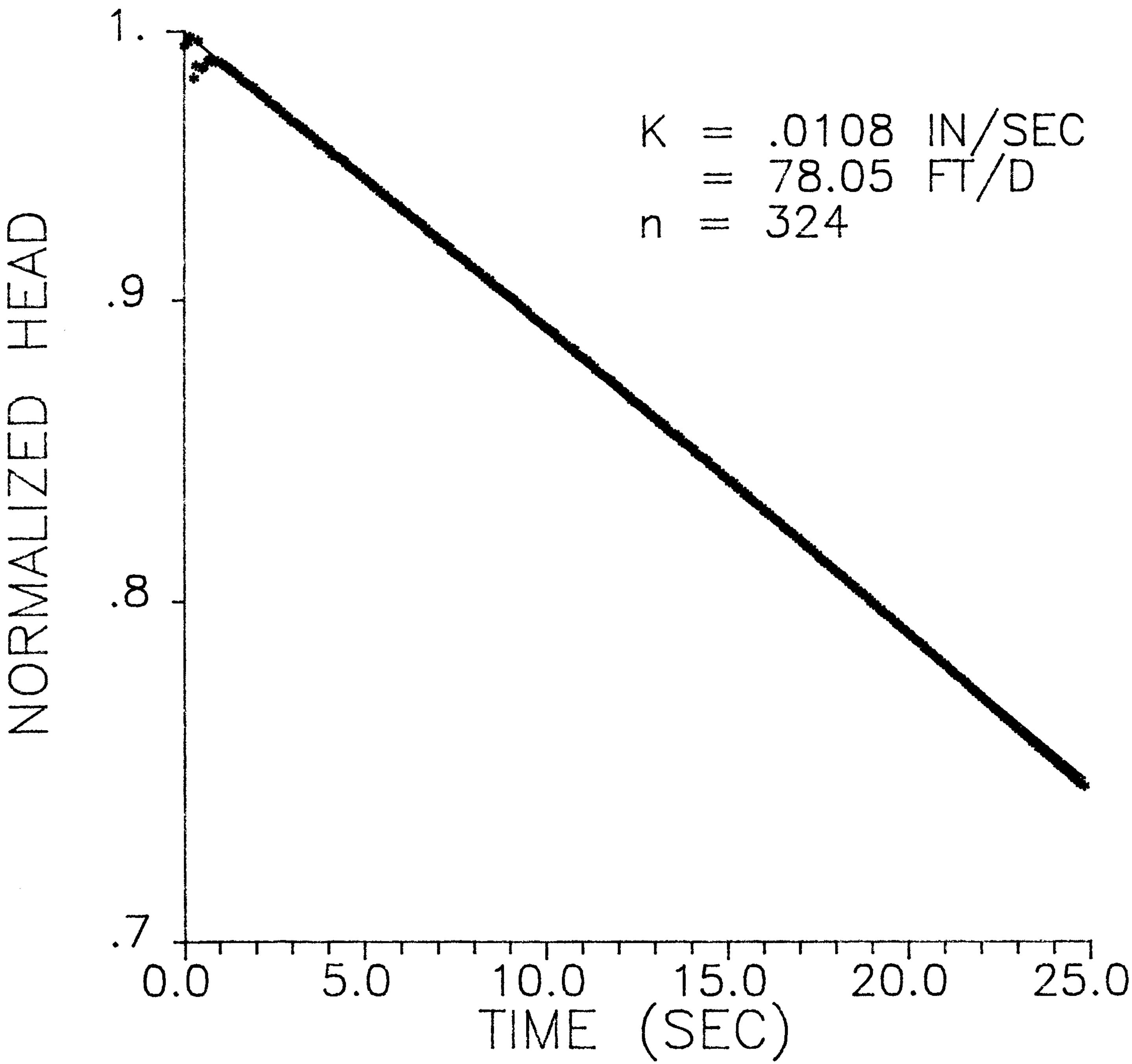





SL-2NW1
5A125,250VAC


ANALOG
DIGITAL I/O
INPUT

Raw data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n = 324
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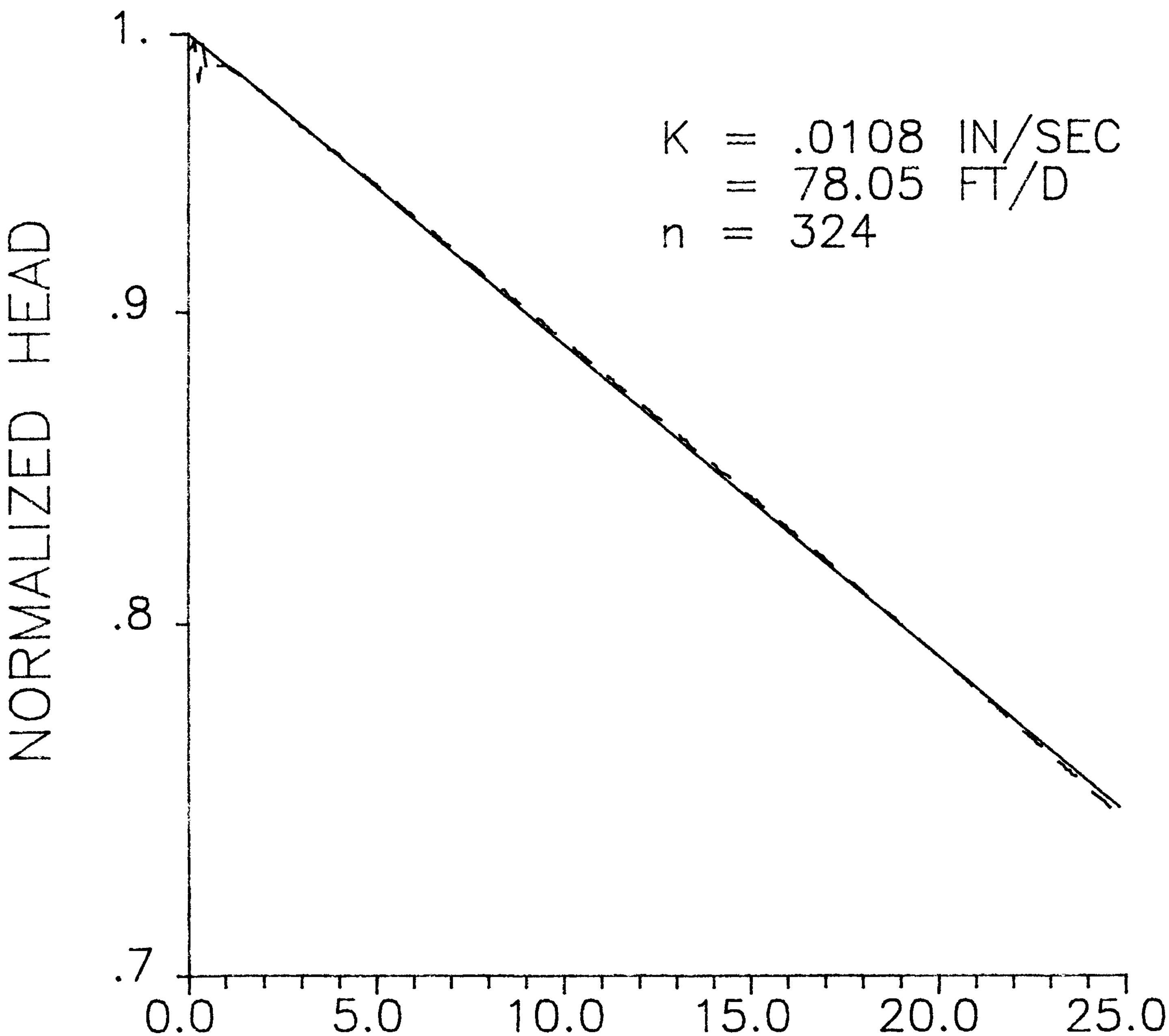
.9
.8
.7
0.0
5.0
10.0
15.0
20.0
25.0
TIME (SEC)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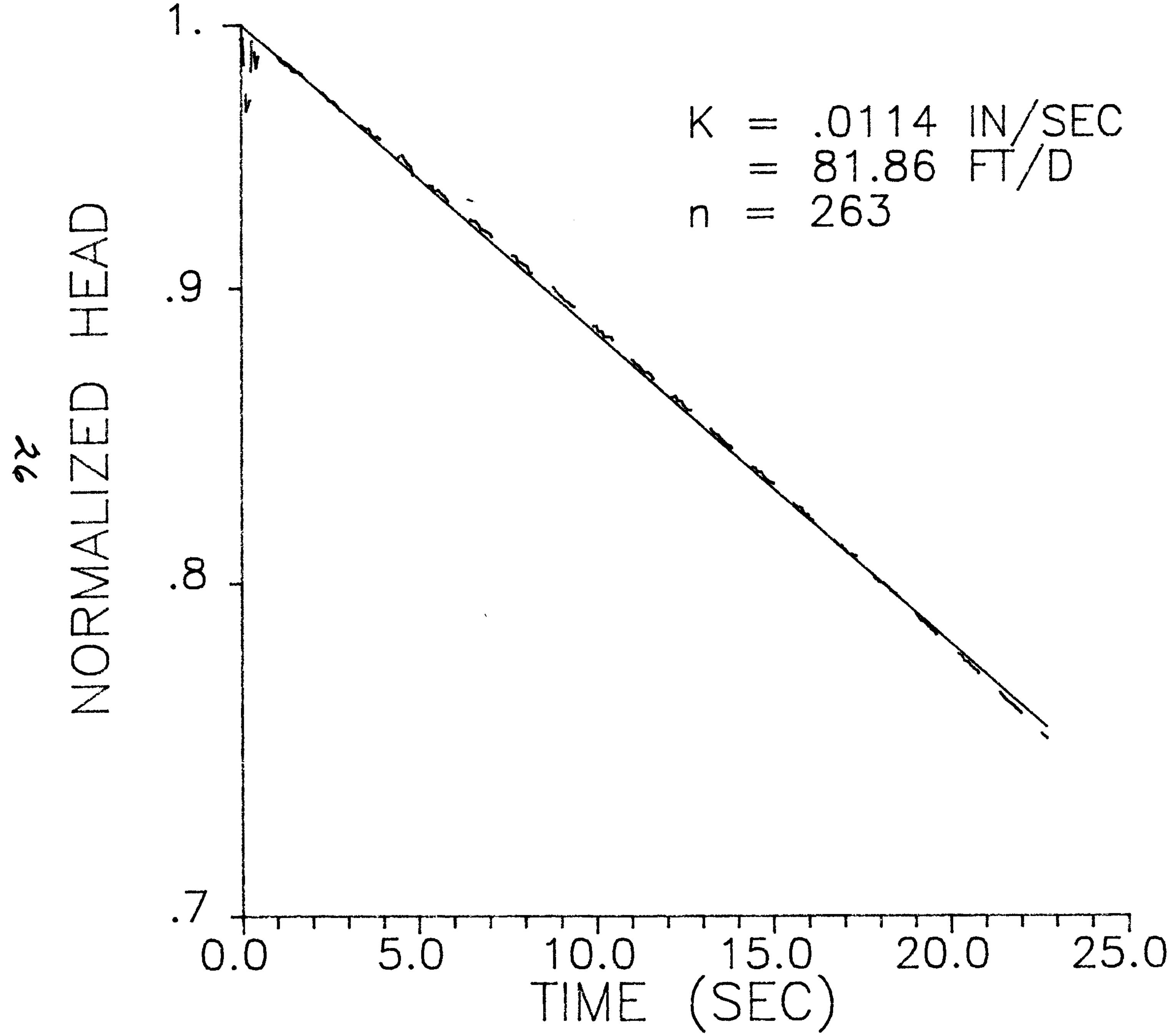
10.0
15.0
20.0
25.0
TIME (SEC)

GSA 55



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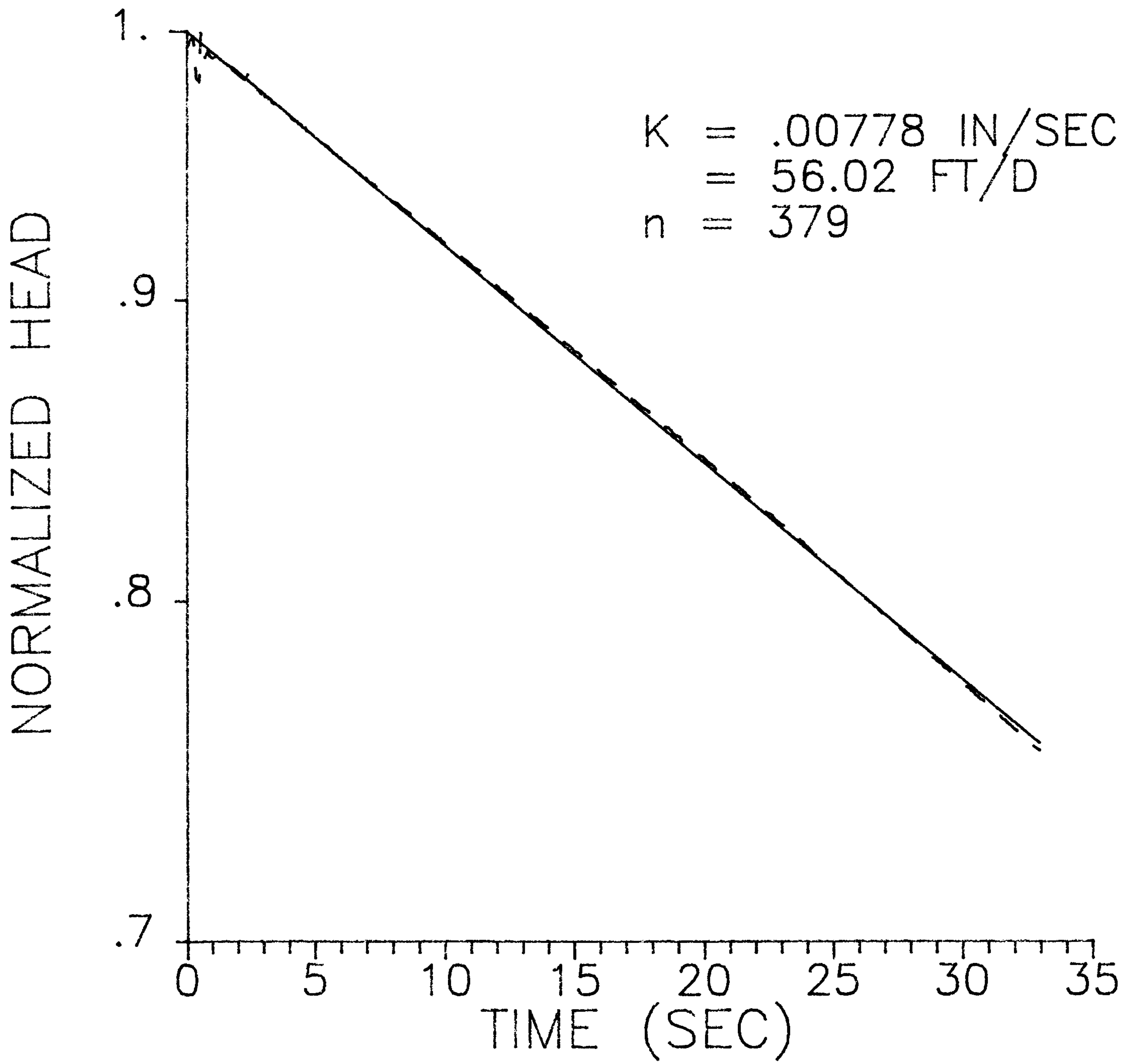
GSA65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n = 379
NORMALIZED HEAD
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.9
.8
.7
0
5
10
15
20
25
30
35
TIME (SEC)

27

SUMMARY

SLUG-TEST SYSTEM FEATURES

1. INNOVATIVE PACKER
2. ABOVE-GROUND RESERVOIR
3. TRIGGER
4. HIGH DATA DENSITY
5. AUTOMATED ANALYSIS