DRP-4-06
May 1992

Dredging Research Technical Notes

Evaluation of Production Meter Performance in a Fine-Grained Sediment Environment

Purpose

This Technical Note provides information that will be useful in estimating the merits of a dredge production meter system. It summarizes the testing and evaluation of a production meter system installed on the hopper dredge *Wheeler* while dredging in a fine-grained sediment environment. Production meter data are used to calculate hopper load for a comparison to the more conventional method of using a load-displacement meter for load determination. Issues such as instrument accuracy and dependability are addressed.

Background

Production meters are valuable tools for providing guidance to dredge operators. Conventional production meter systems consist of a velocity meter and a density meter interfaced with an analog output display which indicates dredge production in units of volume or mass of material moving through the dredge pipe. Because of questions pertaining to meter reliability and accuracy, especially when dredging in fine-grained sediment environments, these systems are generally used only to provide the dredge operator with information on the approximate optimum solids flow rate in the pipe and are not used to monitor and record dredge production.

Tests were conducted to evaluate the accuracy and reliability of production meters in a fine-grained sediment environment. Hopper loads were calculated with the production meter data for comparison to load calculations performed by a load-displacement system also installed on the dredge. The results of this study will provide users of these systems with additional data on using production meters for accurately calculating dredge production.

US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

PRINTED ON RECYCLED PAPER

Additional Information

Contact the author, Mr. Stephen H. Scott, (601) 634-4286, or the manager of the Dredging Research Program, Mr. E. Clark McNair, Jr., (601) 634-2070, for additional information.

Note: The contents of this technical note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products.

Introduction

The Dredging Research Program (DRP) work unit Production Meter Technology has investigated production meter accuracy and reliability through laboratory studies, industry surveys, and dredging trials. These studies have generally indicated that a production meter consisting of a properly calibrated magnetic flowmeter and nuclear density gage is capable of measuring dredge production with good accuracy. It is generally accepted that in coarse materials (sand), the nuclear density gage produces accurate data.

The final task to be completed under this work unit was to test and evaluate the accuracy and reliability of production meters when dredging fine-grained materials such as silts and clays. To accomplish this task, data acquisition instrumentation was installed on the Corps dredge *Wheeler* to record slurry velocity and density data from the production meters installed on each of the three dragarms. Concurrently, hopper load data were continually collected on the dredge through a load-monitoring system installed by IHC Holland. The study consisted of a comparison between dredge production calculated with the production meter and with the load meter. The dredge was working at Sabine Pass near Port Arthur, Texas, in a fine to medium silt sediment.

Wheeler Description

The *Wheeler* is a large trailing suction hopper dredge, with a length of more than 400 ft. Three dragarms, two side dragarms with 28-in. suction pipes and a center dragarm with a 42-in. suction pipe, are used to fill the 8,000-cu-yd hopper. The dragarms are all equipped with production meters consisting of nuclear density gages and magnetic flowmeters. With only the center dragarm in operation, the hopper fills in approximately 15 to 20 min at an approximate inflow rate of 25,000 to 30,000 cu yd/hr.

The *Wheeler* is generally assigned to duty at the mouth of the Mississippi River, in the Southwest Pass and Head of Passes areas, or in the Sabine Pass area. Occasionally, the *Wheeler* will perform emergency dredging operations on the Mississippi River, around Baton Rouge, Louisiana. Sediment composition at these locations varies. At Baton Rouge, the sediments consist almost entirely of fine sands and some organic material, with an average in-place density of approximately 1.9 g/cu cm. At Southwest Pass near the mouth of the Mississippi, the top layer of sediment consists predominantly of silt with some fine sand, with predominantly sand found at lower depths. The sediments found around Sabine Pass are predominantly fine to medium silts, with an average in-place density of about 1.47 g/cu cm. Sabine Pass was the location of the production meter study.

Wheeler Production Meter Description

The production meters were installed on the *Wheeler* by IHC Holland. Each of the three dragarms has a nuclear density gage and magnetic flowmeter installed. The production meter system was manufactured by Observator, a Dutch company. Magnetic flowmeters are intrusive meters, with electrodes penetrating the pipe wall. The installation of these meters requires installation of a separate pipe section into the dredge pipe. The production meter output is directed to a processor in the pilot house and displayed on an analog cross-point display unit. The cross-point display indicates the optimum solids flow rate in the pipe along with the production rate of material in the pipe. The data are displayed only and not recorded. Only data from the center dragarm production meter were monitored during the study.

Production Meter Data Acquisition

A personal computer with an RS232 data acquisition interface was used to log the production meter data. Software developed by the Instrumentation Services Division (ISD) of the U.S. Army Engineer Waterways Experiment Station (WES) recorded the data in binary format on the computer hard disk for storage efficiency. The software was developed with the capability of calculating real-time production in in-place cubic yards and providing output of production as a function of time. The program can be changed to calculate the total production and display it for any time interval during the dredging cycle. Changes in physical dredging variables, such as water density or sediment in-place densities, can be input into the program with a few keystrokes. Both the production meter and flowmeter output were sampled every second, with 10-sec data averages recorded in the data files. Recording 10-sec averages in binary format allows the data to be recorded for months at a time before the hard disk reaches its full capacity. Commercial software was used to reduce and analyze the field data.

Wheeler Load-Measurement System

A load-displacement monitoring system was installed on the *Wheeler* to measure the load in the hopper. This system uses a hydrostatic pressure bubbler gas system attached at the bow and stern of the vessel to relate the hydrostatic pressure change to vessel draft, and converts draft to hopper load through vessel load-displacement tables. The bubbler pressure output is converted to load and displayed on a chart recorder in the pilot house. The load data, along with measurement of the volume of water in the hopper before the load begins, is used to calculate the production of each load in in-place yards. The system is calibrated by filling the hopper with water of a known density and recording the total weight of water for a full hopper with a volume of approximately 8,000 cu yd. Water calibration tests performed by WES indicate that the load-displacement system was capable of measuring the load to within approximately 2 to 5 percent.

Test and Analysis Descriptions

The production meter data acquisition hardware was installed on the *Wheeler* during summer 1991 while the *Wheeler* was operating in the Mississippi River below Baton Rouge. The dredge was reassigned to the Galveston, Texas, area in September 1991 and worked there until reporting to a shipyard in Mobile, Alabama, in late November. Production meter data were continuously recorded during this 3-month period. The production meter data selected for this study were recorded for two days in September at the Sabine Pass location. Twenty-three loads recorded within a 2-day period were analyzed, with only the center dragarm in operation.

The analysis consisted of comparing hopper load data from load-displacement measurements with production meter load calculations resulting from the data acquisition process. The analysis consisted of two parts — a comparison between the calculation of average density of material input into the hopper per load for the two methods, and a comparison between the calculation of total load in the hopper.

To calculate the average pumped slurry density with the load chart data (Figure 1), the weight of material pumped into the hopper (from the load chart) was divided by the hopper volume available for the slurry. The hopper volume available for the slurry was the total hopper volume (approximately 8,000 cu yd) minus the bin water volume in the hopper before filling. The total load pumped into the hopper was the load recorded from the load chart.

Slurry density and slurry velocity in the pipeline were recorded over the load cycle with the computer. Because of the fine silt sediments being dredged, no overflow was allowed. To accurately calculate the average inflow density and cumulative load pumped into the hopper, starting and stopping times were required for the calculations. The *Wheeler* is

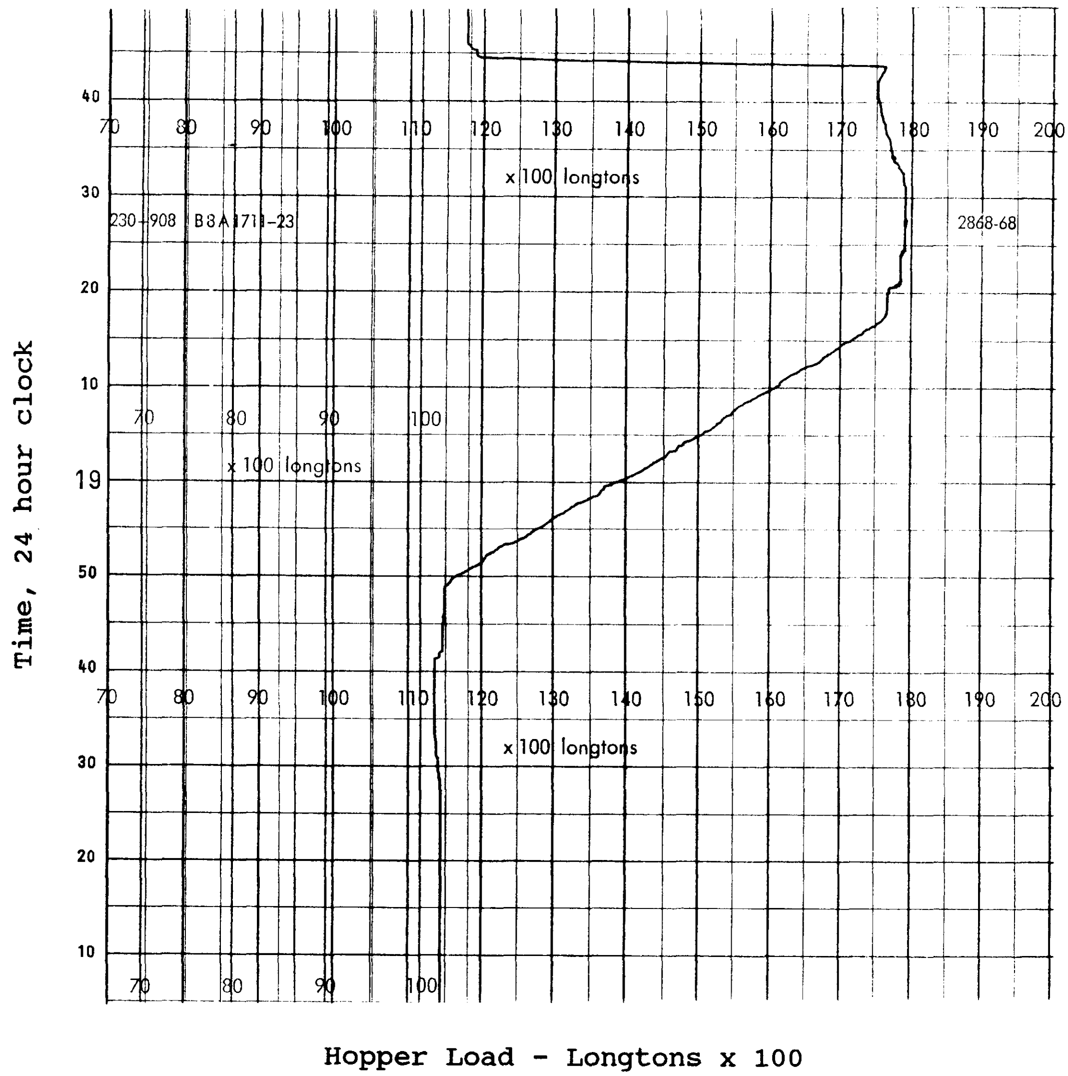

Figure 1. Load chart data from the *Wheeler*

equipped with an Automatic Light Mixture Overboard (ALMO) system, which automatically opens a valve to direct the flow overboard when the density of the mixture falls below 1.05 g/cu cm. When the density of slurry in the pipeline exceeds 1.05 g/cu cm, the filling cycle begins.

During the production meter tests, ultrasonic surface detectors were installed over the *Wheeler* hopper to measure the level of material in the hopper. Data from these sensors indicate when the level of material in the hopper reaches the top of the overflow weirs. This point in the filling cycle was used as the end point for the production meter load calculations.

To calculate the average density of slurry pumped into the hopper, density records for each load were analyzed (Figure 2). All density data recorded for a particular load were summed and then divided by the number of points recorded. To calculate the total load pumped into the

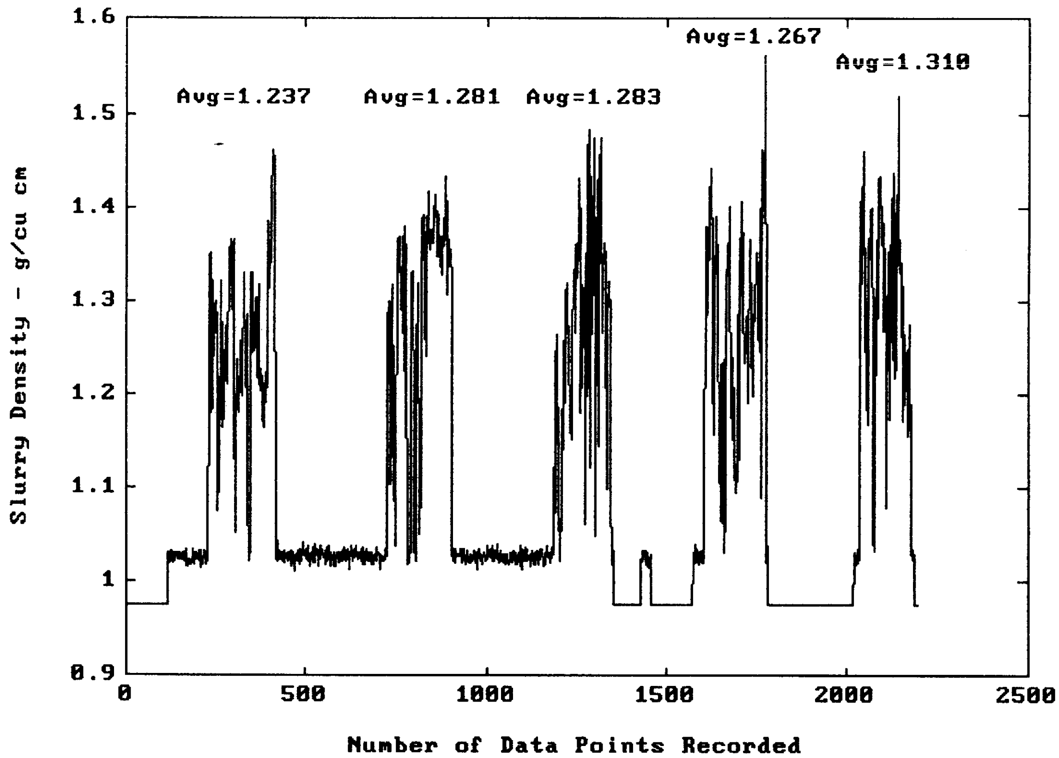

Figure 2. Slurry density data for the first five hopper loads

hopper, each data point recorded for velocity (Figure 3) and density were incrementally summed within an equation describing mass flow to calculate the slurry load in long tons.

Study Results

Table 1 presents the results of the study. The 23 loads are listed with load meter and production meter comparisons of average hopper load density in grams per cubic centimeter, and total hopper load in long tons. Data statistics, mean value, and standard deviation are listed at the bottom of the table. The average hopper load densities calculated by the load-displacement meter and the production meter have almost identical mean values, 1.298 and 1.295 g/cu cm, respectively, and have an average standard deviation of 0.0367 and 0.0369 g/cu cm, respectively, indicating a strong correlation between the two sets of data. On the other hand, the total load data comparison between the two methods reveals that the mean production meter total load calculation, 7,454 long tons, is approximately 20 percent higher than the mean load meter measurement of 6,213 long tons. Also, the standard deviation is substantially higher for the production meter data, 465.1 long tons as opposed to 182.3 long tons for the load-displacement meter data.

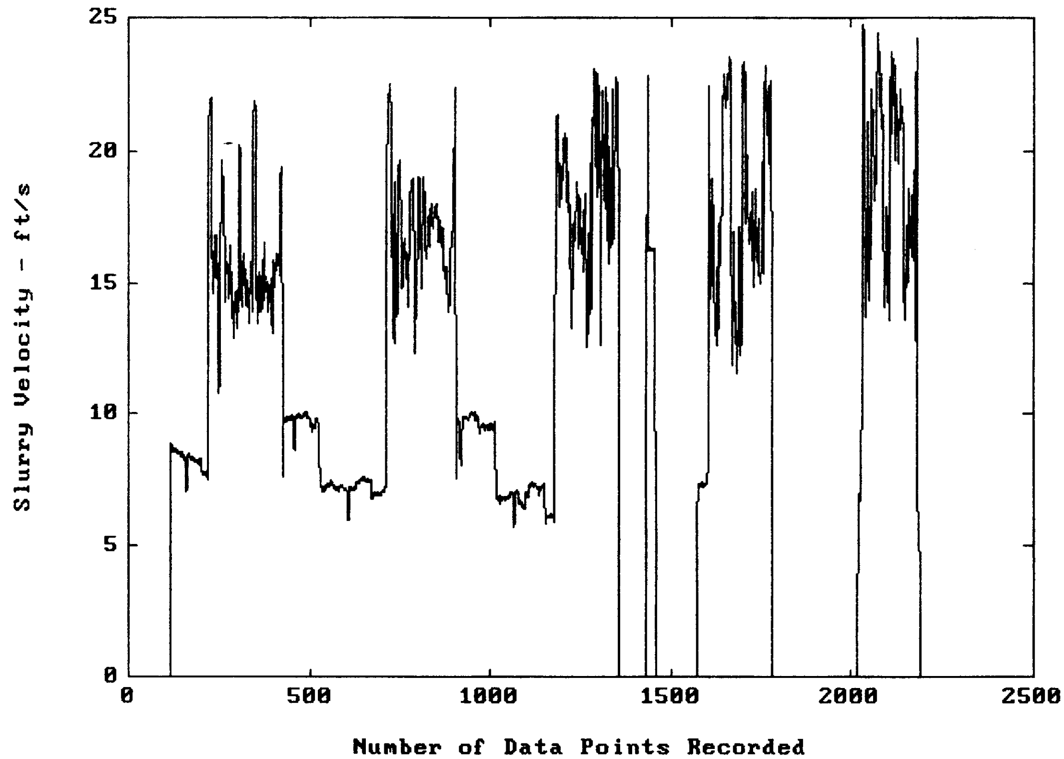

Figure 3. Slurry velocity data for the first five hopper loads

This difference in total load might be explained by the condition of the hopper doors during the study period. The *Wheeler* left for the shipyard for maintenance and repairs about a month after the production study was concluded. About two weeks after the study, the *Wheeler* experienced a failure of one of the hopper doors, requiring emergency repairs. It is possible that the door was experiencing problems with closure during the study period, requiring a longer fill time and subsequently a higher load calculation by the production meter. The production meter load data indicates an almost threefold higher standard deviation from the mean than the load meter data, thus reflecting the varying capability of the hopper to hold its load if the hopper doors were not closing properly during the study period.

Conclusions

WES engineers calibrated the load-displacement meter on the *Wheeler* and determined that the meter accurately reflected the load in the hopper to within 2 to 5 percent. The hopper bin water volume measured by the acoustic sensors over the hopper was also considered an accurate measurement. Therefore, the fact that the two production systems agreed so well on the average slurry density in the hopper indicates that the nuclear density gage data were within acceptable accuracy for the fine-grained

Table 1. *Wheeler* Load Study Comparison Data

Load	Average Load Meter Density, g/cu cm	Average Production Meter Density, g/cu cm	Load Meter Load, long tons	Production Meter Load, long tons
1	1.272	1.237	6,100	7,698
2	1.272	1.281	6,100	7,558
3	1.272	1.283	6,100	7,055
4	1.272	1.267	6,100	7,480
5	1.272	1.310	6,100	7,679
6	1.304	1.349	6,250	8,009
7	1.356	1.339	6,500	7,762
8	1.314	1.343	6,300	7,328
9	1.356	1.317	6,500	6,917
10	1.314	1.346	6,300	7,477
11	1.314	1.313	6,300	8,299
12	1.252	1.238	6,000	7,466
13	1.252	1.262	6,000	7,787
14	1.314	1.285	6,300	7,095
15	1.293	1.296	6,200	7,269
16	1.272	1.264	6,100	6,424
17	1.397	1.314	6,700	7,649
18	1.335	1.336	6,400	6,731
19	1.293	1.303	6,200	7,824
20	1.283	1.214	6,150	6,615
21	1.252	1.295	6,000	7,718
22	1.293	1.277	6,200	7,771
23	1.293	1.315	6,000	7,842
Mean value	1.298	1.295	6,213	7,454
Standard deviation	0.0367	0.0369	152.3	465.1

sediments dredged. The accuracy of nuclear density gages when dredging fine-grained material has been a point of contention among users in the dredging industry. This study indicates that, provided the density gages are calibrated and maintained, reliable, accurate density determination in the pipeline is possible when dredging fine silts.

The total load calculation with the production meter requires an integration of velocity and density measurements over the dredging cycle. This requires an accurate method of slurry velocity measurement, such as the magnetic flowmeter. These meters, when properly calibrated and serviced, have proven to measure velocities to accuracies of less than 1 percent of full scale. The use of production meters for calculating production on a load-to-load basis for hopper dredges may be limited due to overflow and leakage through hopper doors, but for calculating the total production of dredged material through the pipeline for a given project, production meters can provide a reliable and accurate measurement of dredge production.

Acknowledgements

The execution of this and earlier studies was made possible by access to the *Wheeler.* The Dredge Management Section, Dredging Operations Division, of the Corps' New Orleans District is acknowledged for their cooperation and guidance in assisting WES in planning and implementing research projects on the *Wheeler.*