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CORPS OF ENGINEERS

MISSISSIPPI RIVER COMMISSION

MODEL STUDY OF SUCTION HEAD, DREDGE JADWIN

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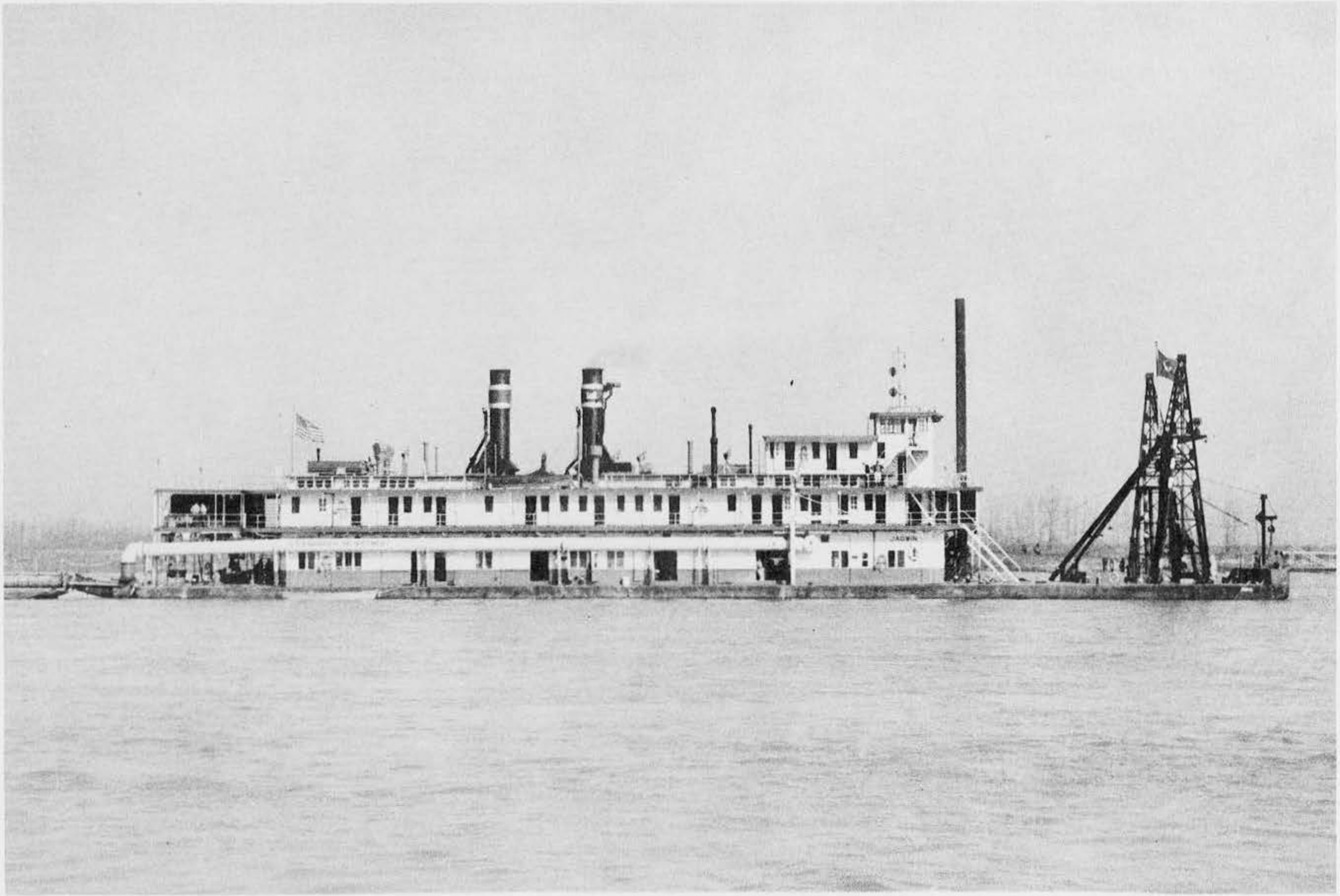

THE DREDGE JADWIN

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MODEL STUDY

OF

SUCTION HEAD, DREDGE JADWIN

SYNOPSIS

The study reported herein was conducted by the Waterways Experiment Station for the Memphis District, Corps of Engineers. The purpose of the study was to investigate by means of a small-scale hydraulic model the performance of a newly-designed suction head for the dredge JADWIN, and to obtain data and information on the operation of both original and new-type heads constructive toward achieving a design of maximum efficiency.

Two basic types of suction heads were initially scheduled for study: the original flared-wall double-dustpan head and a new-type single-dustpan head designed by the Memphis Office. Subsequently, tests were also made of a straight-line modification of the original double-dustpan head. The study included investigation of such design considerations as: the effect of baffles installed in the suction heads and suction lines; the effect of changed alignment of the side walls; the change in output that might be effected by changing the number of regular jets, or by the addition of end jets; the effect on dredge operation of changing the floor design from a flat floor to one with a raised center section; and determination of the optimum ratio between the cross-sectional areas of suction-head opening and suction pipe.

Results of the model tests indicated that either a flared-wall

single-dustpan head, or a straight-line double-dustpan head, could be constructed with an efficiency equalling that of the double-dustpan type, and that jet pressure, and to some extent the ratio of suction-head opening area to suction-pipe area, were controlling factors in the efficient operation of the head. While the tests did not prove that either design was outstanding in performance, they did indicate certain improvements which could be made to increase the efficiency of the head. On the model, the greatest gain in output was obtained by the addition of an end jet of new design. It was also found that a greater output was obtained when the jet pressure was increased from 10 to 15 psi, and that this gain was only slightly augmented by a further increase of jet pressure from 15 to 20 psi. The use of baffles in the suction lines and in the straight-line double head, and the use of jet spacings greater than 11 inches, decreased the efficiency of the head. Further, it was found that no advantage would be gained from use of the raised-floor design.

PART I: INTRODUCTION

1. During the course of major field repairs and alterations, conversion of the suction line on the dredge JADWIN provided opportunity for the Memphis District, CE, to consider changes to the design of the suction head which would effect greater yardage output. Basically, the new design contemplated a single-dustpan suction head to replace the original double-dustpan design. The proposed new design was intended to provide higher velocities in the two wing sections than in the center section; this was based upon the requirement that the wing sections must operate at greater efficiency in order to remove additional material which caves into the dredge cut from its sides as the operation advances. Furthermore, it was realized that the single-dustpan head, even though it should prove to be no more efficient than the double-dustpan head, possessed an inherent advantage in that no center ridge of material would be left in the dredge cut in case the head was overloaded. The primary objective of the model study was, then, to determine the best design of the new suction head in terms of efficiency and performance, with particular reference as to whether the single- or double-dustpan type of construction was preferable. Should the new design fail to effect substantially improved efficiency, an alternative objective was to investigate a simplified, straight-line construction for the original double-dustpan head for purposes of economy in fabrication.

2. Authority for the model study was initially granted by the Chief of Engineers in the second indorsement to a letter from the District Engineer, Memphis District, CE, dated 30 April 1942; a second

series of tests was authorized in May 1943. The study was accomplished at the Waterways Experiment Station during the period 1 August 1942 to 15 February 1944.

3. In the initial phases of the study the problems involved were reviewed by representatives of the Memphis District Office and the Experiment Station, and at that time basic data in the form of drawings and hydraulic data were furnished by the Memphis District Office. During the entire course of the investigation, close liaison was maintained between the Experiment Station and the District Office by conference; the results of tests were transmitted to the Memphis District at intervals in the form of preliminary reports. Mr. H. S. Gladfelter, Engineer, Chief of the Mechanical and Electrical Section of the Memphis Office was directly in charge of the investigation for that office.

4. The study reported herein was accomplished by the Hydraulics Division of the Experiment Station. Engineers actively concerned with supervision of the study were Messrs. Joseph B. Tiffany, Jr., Executive Assistant to the Director, Eugene P. Fortson, Jr., Joseph M. Caldwell, Eugene H. Woodman, and Walter B. Slay, Project Engineer, assisted by Mr. John B. Clark.

PART II: THE PROTOTYPE

General Considerations

5. The dustpan-type suction head is so named because of the close resemblance of the head to an ordinary household dustpan or vacuum sweeper. River dredge boats equipped with this type suction head are employed for the removal of relatively soft and easily eroded materials, such as those prevailing in the Middle Mississippi Valley, by suction into the dustpan-shaped head. As the dredge advances upstream the suction head is nosed into the bar or other obstruction, where the material is loosened by means of numerous water agitation jets spaced closely across the front of the dustpan. Dredged material, consisting of sand and silt mixed with water, is drawn upward from the dredge head by a centrifugal pump located on the main deck of the dredge boat and thence through a floating discharge pipe, several hundred feet long if necessary, to areas outside the channel suitable for deposition of spoil. Fig. 1 is a sketch of the forward part of such a dredge boat with its suction head in operation at a depth of 40 ft.

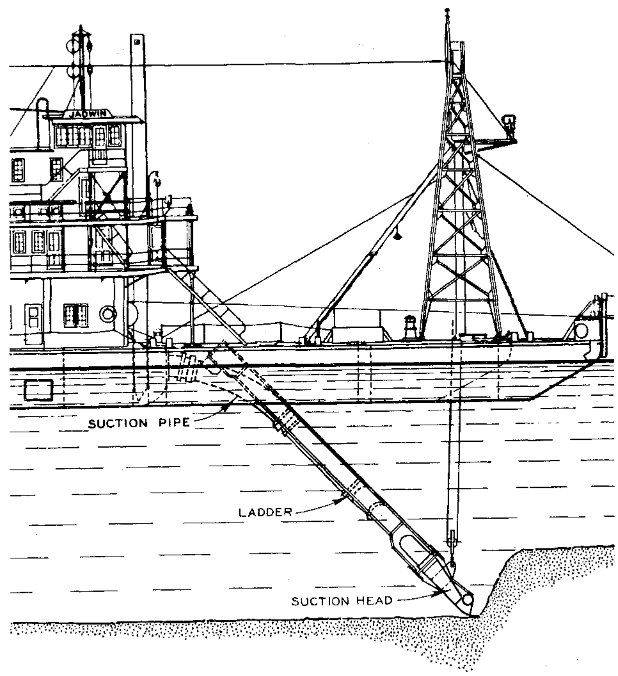

Fig. 1

Dustpan-type suction head in operating position

6. The dredge head, shaped as indicated by fig. 2, is known as the double-dustpan type, and has an effective height of entrance passage of approximately 1 ft just behind the jet pipes and trashrack. Above the dustpan is a header supplying the individual jet orifices spaced across the entrance of the dustpan; typical data for these jets are a total discharge of approximately 11,000 gpm with pressures of 7 to 10 psi at the point of effusion. The plan view of fig. 2 shows the arrangement of these jets approximately 1 ft apart along a 32-ft face. The typical dredge head

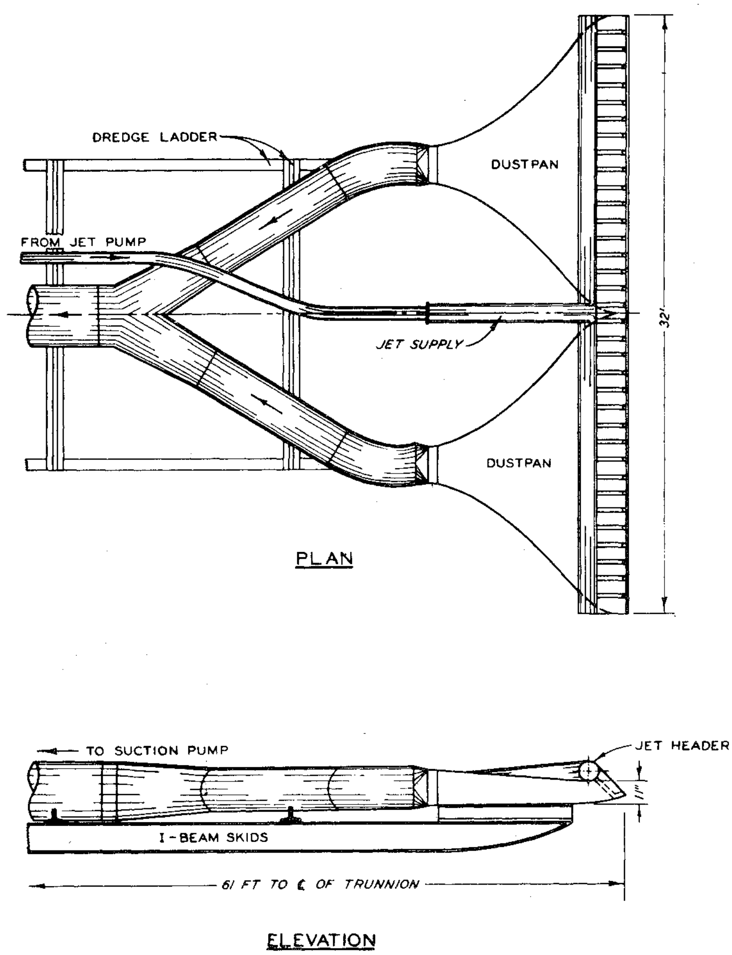

Fig. 2

Typical double-dustpan suction head

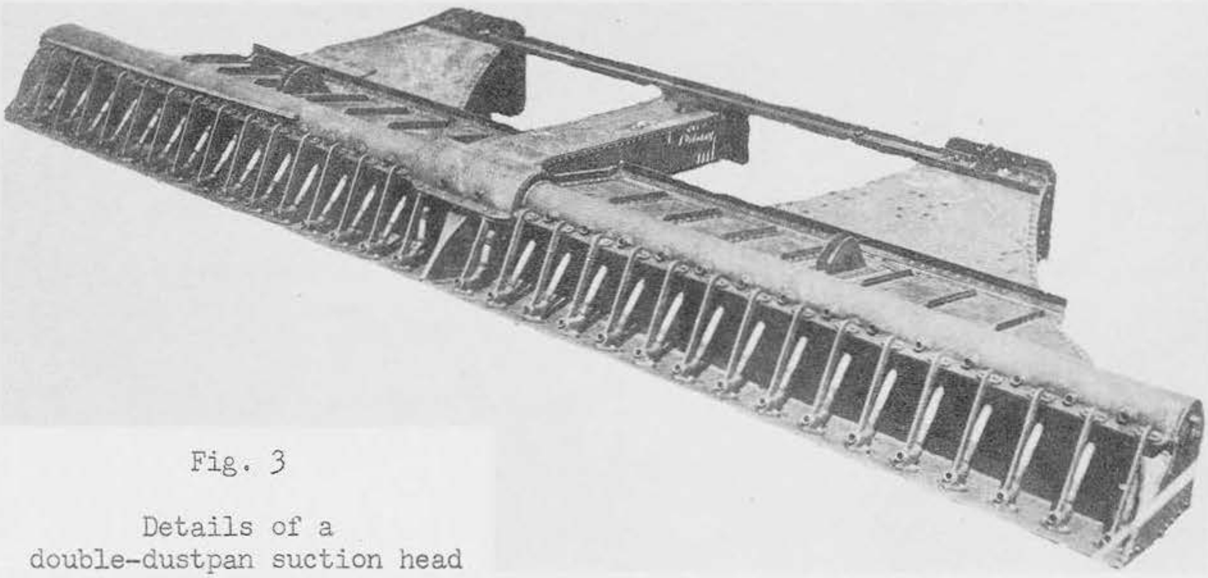

Fig. 3

Details of a
double-dustpan suction head

shown by fig. 3 illustrates this feature in greater detail. The rear of each dustpan tapers to a square cross section, thence through a short transition to a round cross section of corresponding area. In some cases the suction pipes are carried up the dredge ladder (supporting framework) as individual lines to the pump; in other cases, they are joined in a Y-branch connection of larger cross-sectional area before continuing up the ladder to the pump. Typical dimensions for these pipe lines in the class of dredge boats under consideration are 27 in. for the individual lines and 38 in. for the combined line. The discharge capacity of the centrifugal pump ranges from 125 cfs to 160 cfs.

7. Dredges equipped with the dustpan-type suction head are used for improvement, pre-maintenance and maintenance dredging operations over a wide range of depth as indicated in the following tabulation:

	Maximum		Minimum		Average	
Type of Dredging	Bank	Depth	Bank	Depth	Bank	Depth
Improvement	50 ft	40 ft	50 ft	40 ft	50 ft	40 ft
Pre-maintenance	30	40	20	40	25	40
Maintenance	15	20	5	18	10	20

In the above tabulation, Bank is defined as the thickness of the material to be removed (depth of cut) and Depth is defined as the distance the suction head is lowered below the water surface to accomplish same. (Since dredges having the dustpan type of suction head are generally engaged in maintenance dredging, it was particularly desired that any improved design be tested under the average conditions for maintenance dredging as listed above, and the model was so designed.)

8. With regard to the over-all accomplishment of a finished dredge cut, each passage of the dustpan dredge over the area to be deepened results in a longitudinal cut of trapezoidal cross section, having a bottom width equal to the width of the suction head and side slopes determined by the natural angle of repose of the dredged material and the degree of disturbance imparted by passage of the dredge. Widening of the cut to the desired channel dimension is secured by repeated longitudinal overlapping passages of the dredge. The rate of advance of the head in the dredge cut is thus of paramount significance, since too high a speed can result in loss of material around the ends or over the top of the suction head, while too slow a speed will result in a lower per cent of solids dredged, or less yardage output per unit of time. A nominal rate of advance may be taken as 300 ft per hr with 10 to 20 per cent solids being dredged, this material containing from 85 to 95 per cent sand with the remainder varying from pea gravel to coarse gravel.

The Prototype

9. Specifically, this study was concerned with the testing of a new suction head for the dredge JADWIN. The original suction head on

this dredge was of the double-dustpan type, 32 ft in effective width, with a controlling entrance height of 11 in. under the jet header. Jetting action was supplied by 34 jets spaced on 11-in. centers across the front edge of the dredge. Connection from the suction head to the pump consisted of two 27-in. suction lines connected to a Y-branch just below the pump. Because the new design of head was to have a single 38-in. pipe leading from the suction head to the pump, this particular feature of the original head was altered for model construction purposes (for ease of interchangeability of model heads) to agree with the suction-line assembly of the dredge BURGESS, wherein the two 27-in. lines from the suction head are joined immediately above the head into a 38-in. line leading to the pump. As the dredge BURGESS was quite similar to the dredge JADWIN, both as regards construction and performance, no compromise in model results was occasioned by this substitution of suction-pipe arrangement. Fig. 4 shows the suction head from the dredge OCKERSON

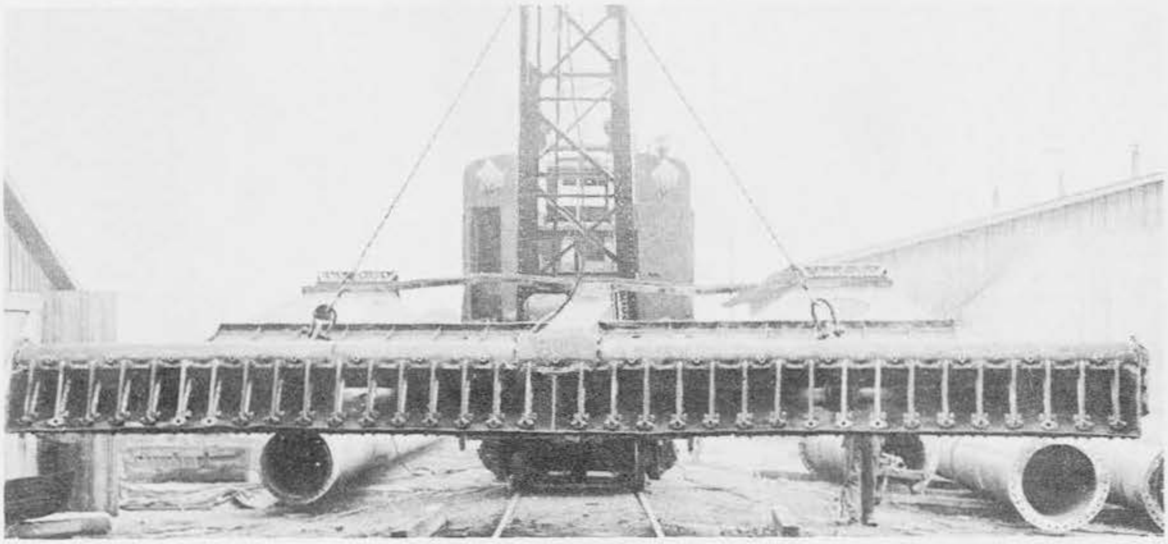

Fig. 4

Jet arrangement of a double-dustpan suction head removed from the dredge for servicing in the yards of the Engineer Depot at Memphis. Constructional features of this head are almost identical with the suction head for the dredge JADWIN as described above.

PART III: THE MODEL

Similitude

10. In order for any hydraulic model to reproduce accurately the flow conditions of its prototype, it is necessary that similarity, both in a geometric sense and with respect to the forces predominantly affecting fluid motion, exist between the two systems. In the hydraulic system under consideration in this case, the force of gravity was predominant in its effect upon the inertia of fluid particles. Accordingly, geometric and dynamic similarity between model and prototype were established by constructing all pertinent features of the dredge head to an undistorted linear scale ratio, and by then treating all hydraulic quantities in their proper relationships as derived from the Froude law.

The Model

11. A linear scale ratio of 1 to 10, model to prototype, was selected for this model study. This resulted in a model dredge head with a width of 3.2 ft and a length from the water entrance to the trunnion on the dredge ladder of 6 ft. The model of the original double-dustpan suction head is shown in fig. 5. The model heads were constructed of sheet metal and pyralin (a transparent plastic), reproducing prototype dimensions to scale from the lip of the dustpan to a point on the suction line just opposite the ladder trunnion. No attempt was made to reproduce the trashracks and cover plates in the models as this would have added nothing to the hydraulic similarity of the models and would have

interfered with the tests. The tops of the dustpans and portions of certain of the Y-branches were constructed of pyralin so that the action of water and sand within the heads and suction lines could be observed.

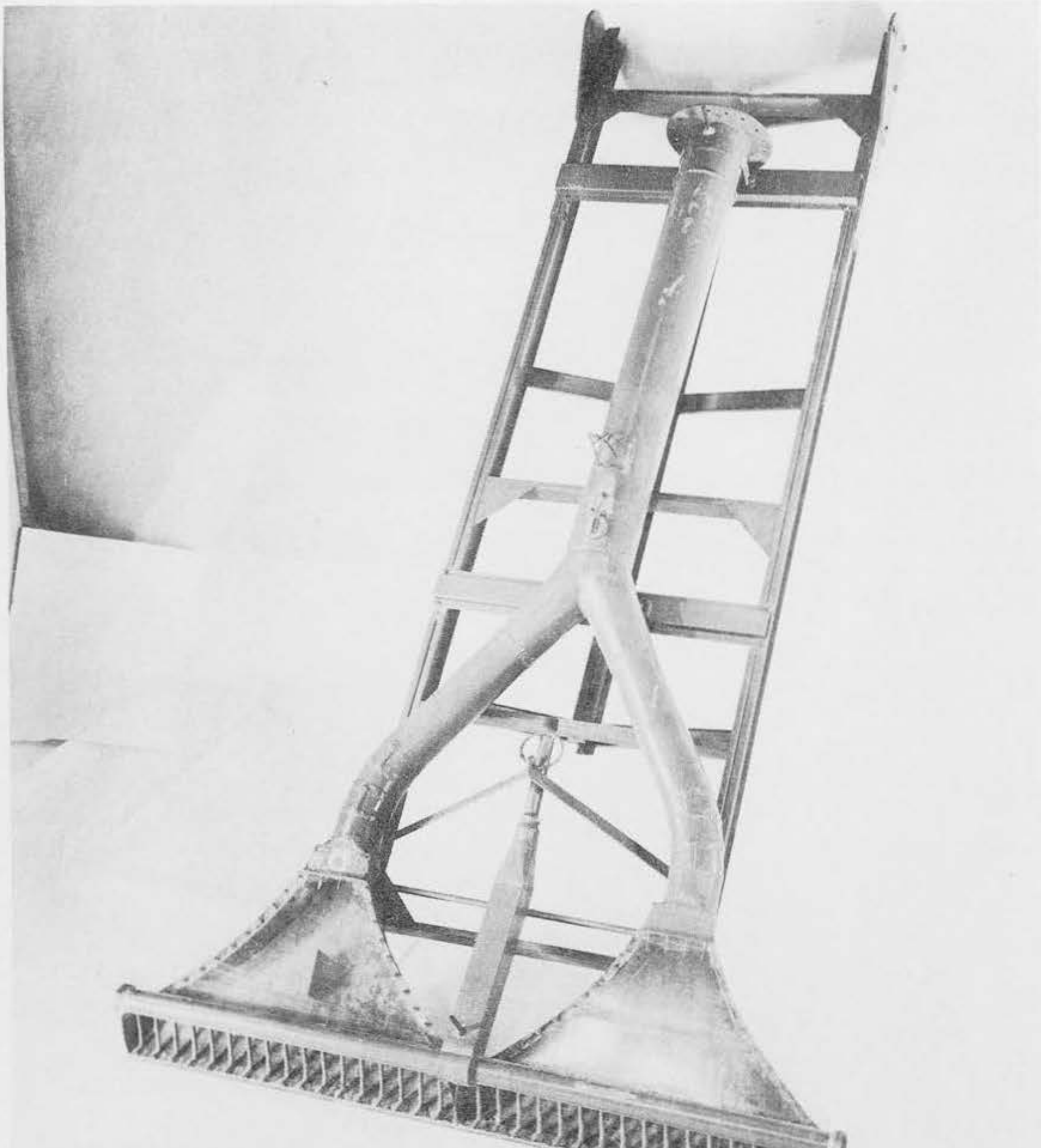

Fig. 5

Original double-dustpan suction head as tested in the model

12. From the dredge head, the 3.8-in. suction line and 1.5-in. jet line were connected to a suction pump and jet pump, respectively. These pumps were so mounted on a double carriage that travel, both longitudinally and transversely across the cut, could be obtained. Longitudinal travel was regulated by means of a vari-speed drive to give any desired speed comparable to the speed of the prototype. This motorized carriage traveled on rails extending the length of a 16-ft flume containing a sand bed of sufficient depth to allow a maximum bank of 15 ft (prototype) with a depth of 35 ft and a length of cut of approximately 60 ft, the exact length depending on the depth of cut made. Provision was made for simulating river flow on the model, should this necessity develop, although since the model equivalents of river velocities would not produce movement of the sand bed, this was considered an unlikely requirement, which conclusion was borne out in the subsequent experiments.

13. The complete model layout used in this investigation is shown in fig. 6. It consists of a flume 16 ft by 10 ft by 4 ft deep, spanned by the previously-mentioned carriages supporting the suction head, suction pump, and jet pump. The manually-operated cross-motion carriage allowed the suction head to be positioned crosswise of the sand bed, while the motorized carriage was used to move the suction head lengthwise of the flume and to force the suction head into the sand bed. The suction pump discharged into a sump. This sump was used to trap the dredged material, and also contained a system of baffles for stilling the water before it was allowed to flow over a 90-degree V-notch weir back into the flume. Trapping and subsequent measurement of the material dredged during each test, together with observation of pump discharge as measured over the

weir, enabled a check on the per cent solids being dredged. Suitably connected manometers provided measurements of suction vacuum and jet pressure. Since it was not practicable to construct the dredge pump, discharge lines, etc., to scale, the action of the dredge was simulated by controlling the discharge through an orifice in the discharge line.

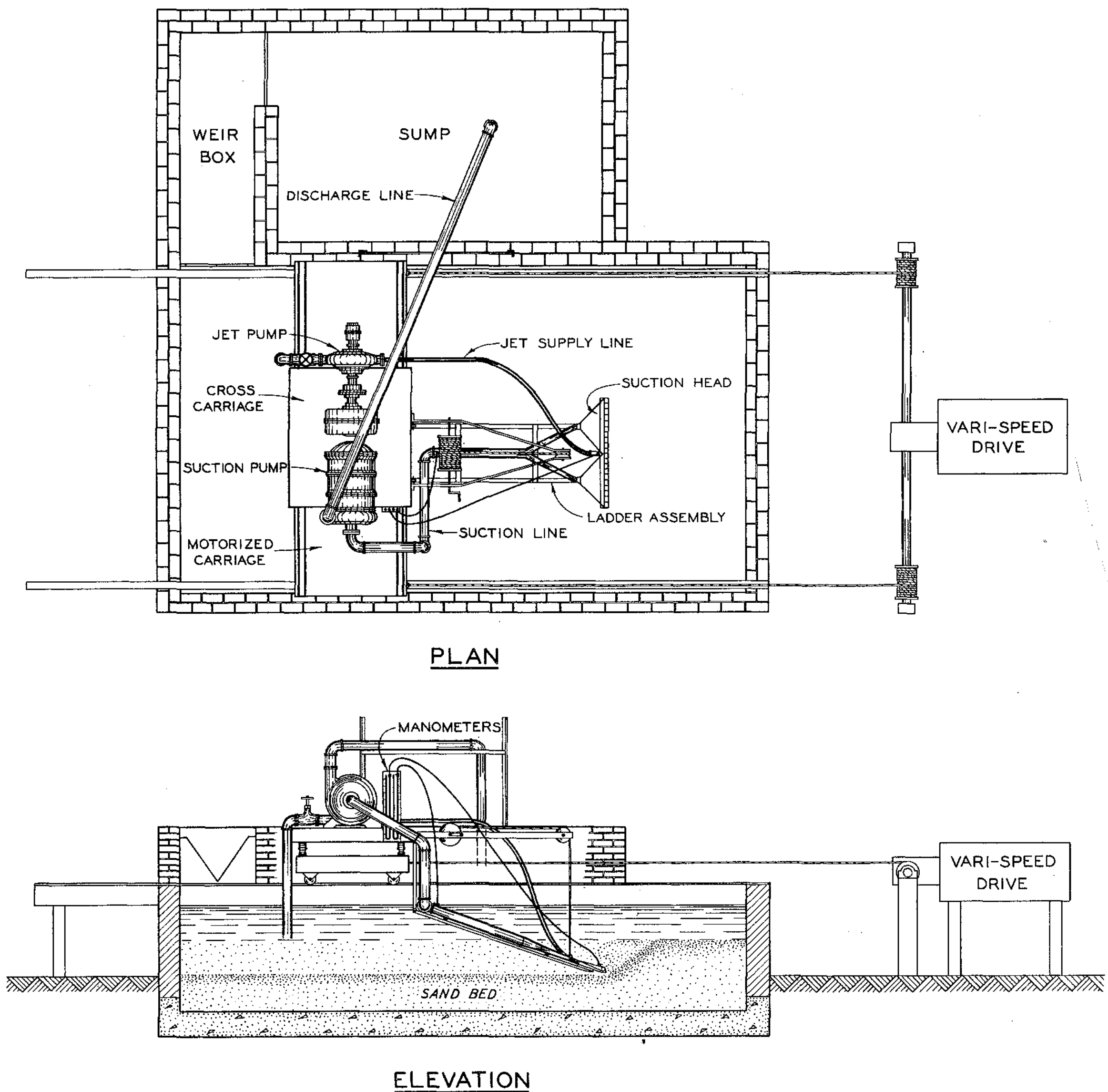

Fig. 6

Layout of the model for testing suction heads

Interpretation of Data

14. Discharges, water-surface elevations, velocities and pressures as measured on the model may be transferred quantitatively from model to prototype by application of the appropriate Froudian scale ratios when considering those tests in which the model was pumping clear water. However, due to the impracticability of reproducing to scale the sand which was used as a bed material, exact similarity was not established for those tests in which the suction head operated in the sand bed. Thus the results of the latter tests are only qualitative in nature, and cannot be translated to absolute prototype terms; this notwithstanding, the results of these tests may be used as a satisfactory basis for comparison between the relative efficiencies and performances of the various designs tested.

PART IV: NARRATIVE OF TESTS

Basic Conditions

15. All of the tests were conducted with a 10-ft bank and a 20-ft depth. A basic rate of advance of 4 ft per min was used for all tests with the exception of those in which the forward speed was increased to determine the limiting rate of advance at which the head would choke up; the maximum rate of advance tested was 7 ft per min, with several values intermediate between 4 and 7 ft per min. The agitation water jets were operated at pressures (measured at the jet header) ranging from 2.6 psi to 20 psi. Normal clear water discharge of the suction pump was taken at 158 cfs and a discharge of 146 cfs was considered nominal when pumping sand, although no adjustment was made to model settings after starting a test with 158 cfs clear water discharge. A suction vacuum of 18 to 20 in. was considered nominal, although no control was exercised over this quantity subsequent to initial adjustment of the model.

16. Under the average conditions specified above, the predicted rate of dredging would be approximately 3200 cu yd per hr, and this value was approximated in initial adjustments of model performance. The rate of cutting in cu yd per hr is used as an index of efficiency in comparing results obtained with the various heads tested.

Model Operation

17. In order to obtain reliable and comparable results from the model tests, it was necessary that a standard method of operation be established. A clear water discharge from the suction pump of 158 cfs,

which corresponded to the average clear water discharge of the prototype, was established as a standard for checking the operation of the suction pump. This discharge was obtained by placing a nozzle at the end of the discharge line to reduce the flow to the amount required.

18. It had been planned before the model was placed in operation that it should operate under a constant suction vacuum throughout any given test. The vacuum was to be held constant by controlling the rate of making the cut, as is done in the prototype, and by means of a valve in the suction line to be controlled by the operator. Should the vacuum become greater than the operating vacuum, the model operator was first to stop the travel of the head and then if the vacuum remained too high, he was to open the suction line valve, thus increasing the entrance area. It was found in practice that the operator could not hold the suction vacuum sufficiently stable for tests to be repeated accurately, and that the resultant cut was not uniform. An attempt to stabilize the discharge by means of a manually-adjusted gate valve placed in the discharge line failed because sand banked against the valve gate, causing a reduction in the discharge. This operational problem was successfully remedied by placing an orifice of the proper size to give a clear water discharge equal to that of the prototype at the end of the discharge line. The size of the orifice was determined from observation of the setting of the gate valve and by experiment. It was then determined from succeeding tests that model and prototype discharges would agree under dredging conditions with reasonable accuracy. As the tests were to be of a comparative nature, it was not profitable to spend excessive time in achieving a more exact reproduction.

19. To prepare the model for operation, the sand bed was levelled to the required elevation, which was 10 ft below the ultimate surface of the water. The head was lowered and adjusted to provide the depth of cut required on that particular test (nominal operating conditions were a 10-ft bank and a 20-ft depth). The head was set at some distance back from the face of the sand bed so that the model could be adjusted while pumping only clear water and so that the jet streams from the suction head would not disturb the sand bed. The flume was flooded slowly so as not to disturb the sand bed until the water had reached the proper elevation; the sump and head bay of the weir were then filled to overflowing. The suction and jet pumps were started and allowed to run while the water in the flume was adjusted to the correct elevation. The correct jet pressure was set by means of the manometer connected to the jet header by adjusting the valve in the jet pump discharge line. The clear water discharge of 158 cfs was checked by means of the sump weir to make certain that the suction pump was operating properly.

20. After setting the rate of advance of the dredge head to the speed selected for the test, the vari-speed motor was started and the head was pulled into the cut at a constant speed. Readings were made each 30 seconds (model time) as the head progressed through the cut; simultaneous readings were taken of suction vacuum, jet pressure, and suction pump discharge. The distance that the carriage moved, together with the elapsed time of the test, was recorded in order to check the speed of travel of the head through the cut.

21. After the cut had been made, it was cross sectioned and the yardage computed in cu yd per hr. Cross sectioning of the bed proved

to be faster and more accurate than measuring the quantity of sand discharged into the sump. A minimum of three sections was measured and averaged for each cut made.

Descriptions of Dredge Heads Tested

22. Four basic models of suction heads were constructed, on each of which a number of alterations were made to test different factors affecting the efficiency of the heads. A description of each suction head, with its chief alterations, is contained in the following paragraphs.

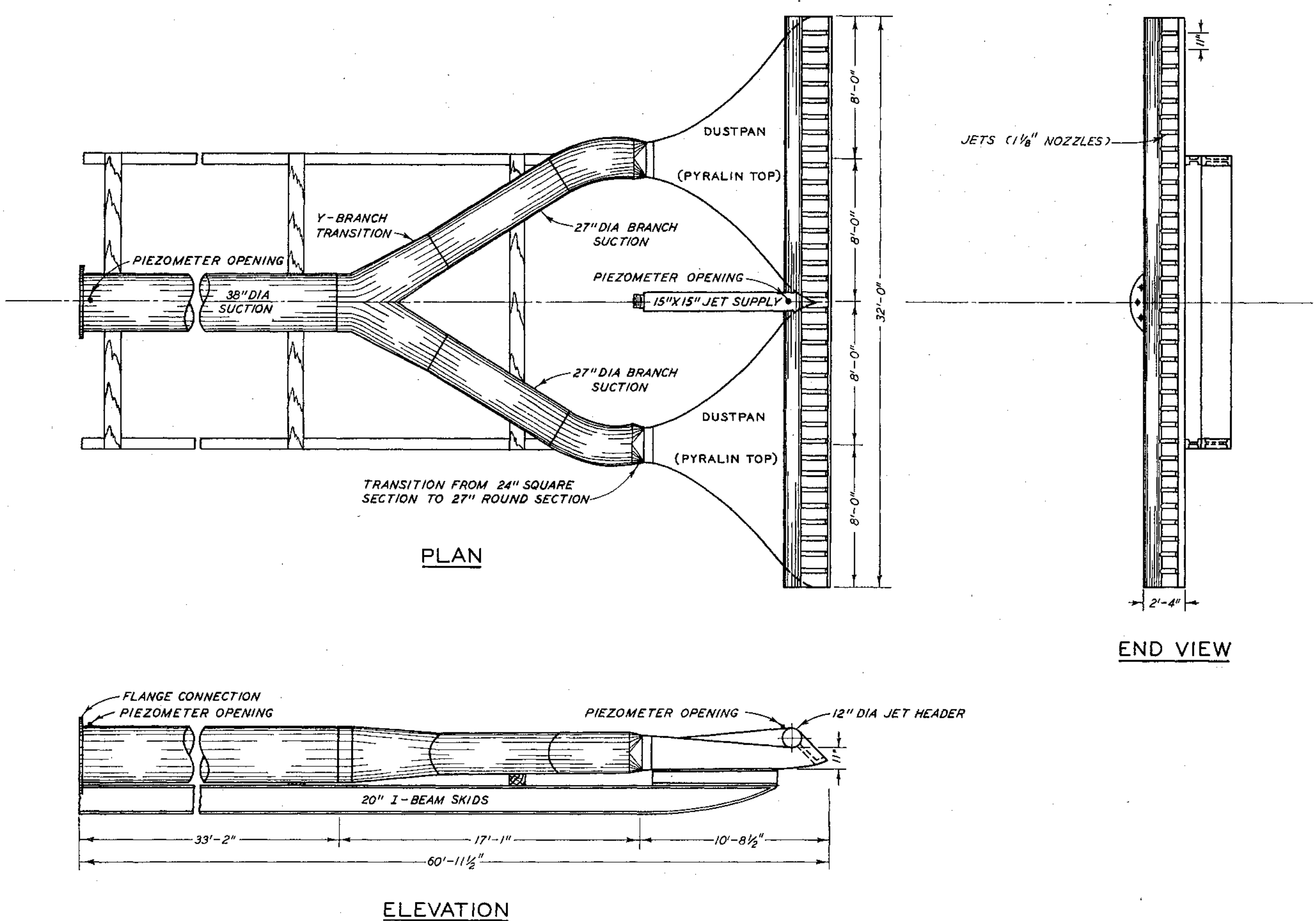

Fig. 7

Dimensions and details of the original double-dustpan suction head

Original double-dustpan head

23. The basic double-dustpan suction head, of which an improved design was sought, was constructed in accordance with the dimensional data contained in fig. 7, while fig. 8 shows a view of the head as actually constructed for the model tests. The double dustpan, the jets, and the jet header of the original dustpan model were reproduced to the model scale from the suction head used on the dredge JADWIN, but the arrangement of the suction lines was modeled after the suction lines used on the dredge BURGESS. This head was used as a basis for determining the relative effectiveness of design features and methods of operation in comparison with the other heads tested.

24. One of the controlling factors to be investigated was the ratio of area of suction opening in the dredge head to area of suction pipe.

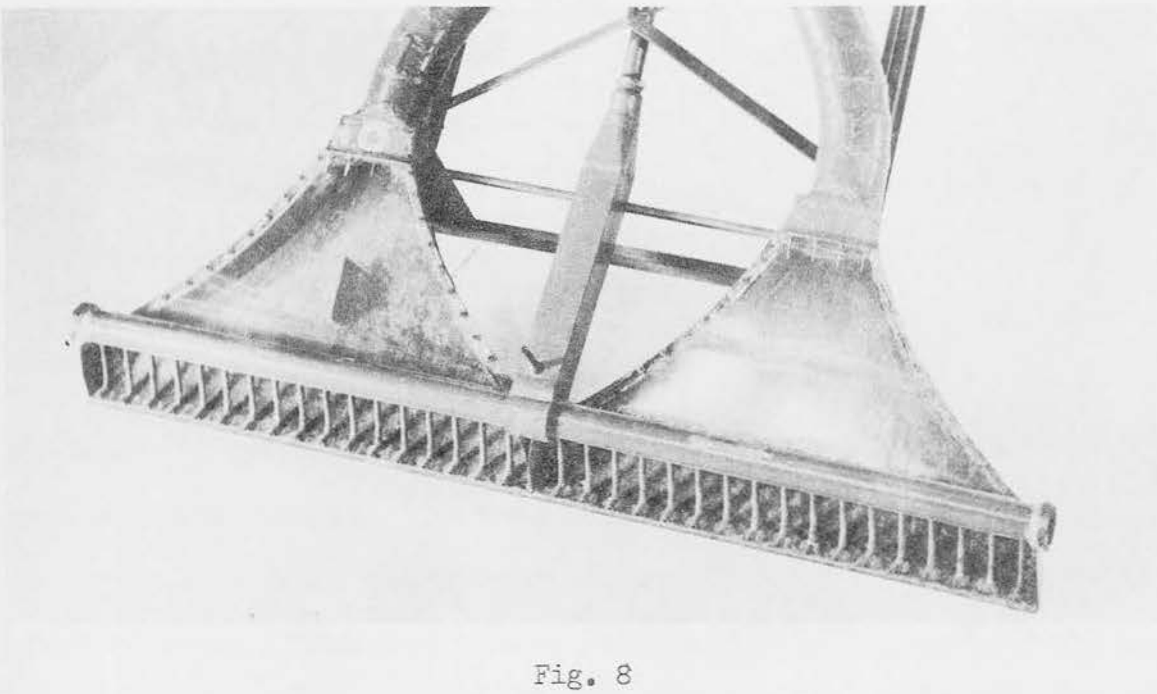

Fig. 8

Arrangement of dustpan and jets
of the original double-dustpan suction head

Thus, in the original double head the area of the suction opening in the dredge head is 29.33 sq ft (32 ft effective width with a controlling height of 11 in. between the jet header and the floor), while the area of the suction pipe is 7.88 sq ft (38-in. diameter pipe); this results in a ratio of 3.72 to 1. It was desired to investigate the range of ratios between at least 5 to 1 and 3 to 1, under the assumption that the ideal ratio was about 4 to 1.

25. In order to test the original design of double head with different ratios of area of entrance opening to area of suction line, the original head was remodeled to give an effective height of entrance opening of 16 in. in place of the 11-in. height of opening shown in fig. 7. False floors constructed in this head were used to give ratios of area of entrance opening to area of suction pipe of 4.04 to 1, and 3.03 to 1, in addition to the ratio of 5.08 to 1 given by the 16-in. entrance opening, and false floors were also used to change the floor from a flat- to a raised-center design.

26. Methods of installing the false floors are shown in fig. 9. Section A-A shows the false floor extending from the nose of the dredge back to the beginning of the transition section; it can be noted that the maximum decrease in height resulting from installation of a false floor occurs at the control section under the jet header, tapering to no change at the nose of the dredge and at the transition section. Section B-B (flat floor) shows the appearance of the false floor with respect to the width of the dredge head at its point of maximum effectiveness under the jet header; this construction is hereinafter referred to as "flat" floor in stating conditions under which tests were made. Section B-B

(raised floor) shows the appearance of the false floor designated hereinafter as "raised" floor; it will be noted that this construction divides the width of the head into thirds with maximum decrease in effective height held constant across the center third and ranging from maximum decrease to no decrease from the center third out to either end. In installing the raised floors, effective heights of openings were so calculated that the ratios noted in paragraph 25 were maintained for comparative purposes.

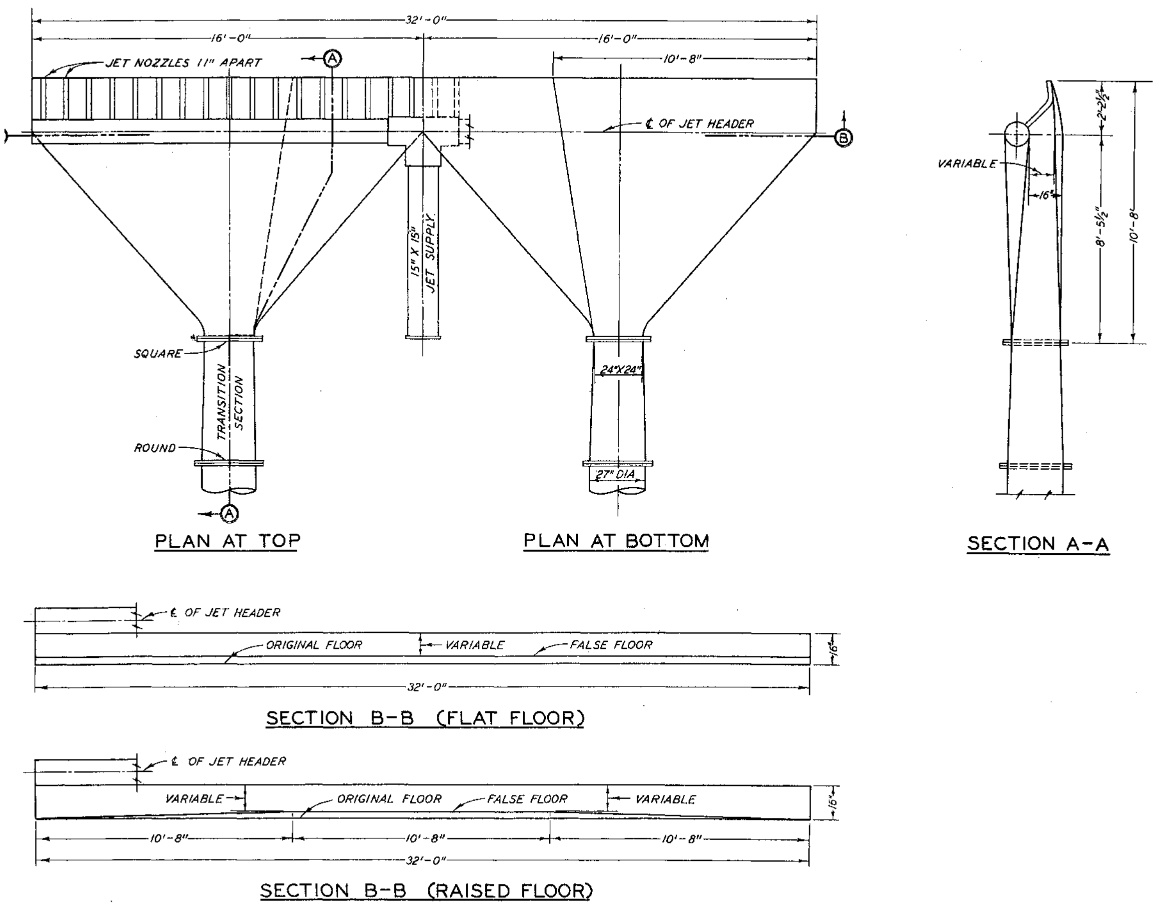

Fig. 9

Details of the method of installing false floors

Flared-wall single-dustpan

27. Fig. 10 and 11 show the features of this head. The head was first constructed with a height of entrance opening of 16 in., and with 23 jets spaced on 16-in. centers. The entrance opening was later reduced to 11 in. by means of a flase floor, using the method shown in fig. 9, in order that the ratio of entrance area to suction pipe area would equal that of the original double-dustpan head. As originally constructed, the baffles were arranged to give effective entrance areas of 33-1/3 per cent of the total entrance area through each of the center and two side entrances. One alteration made to this head during the testing program

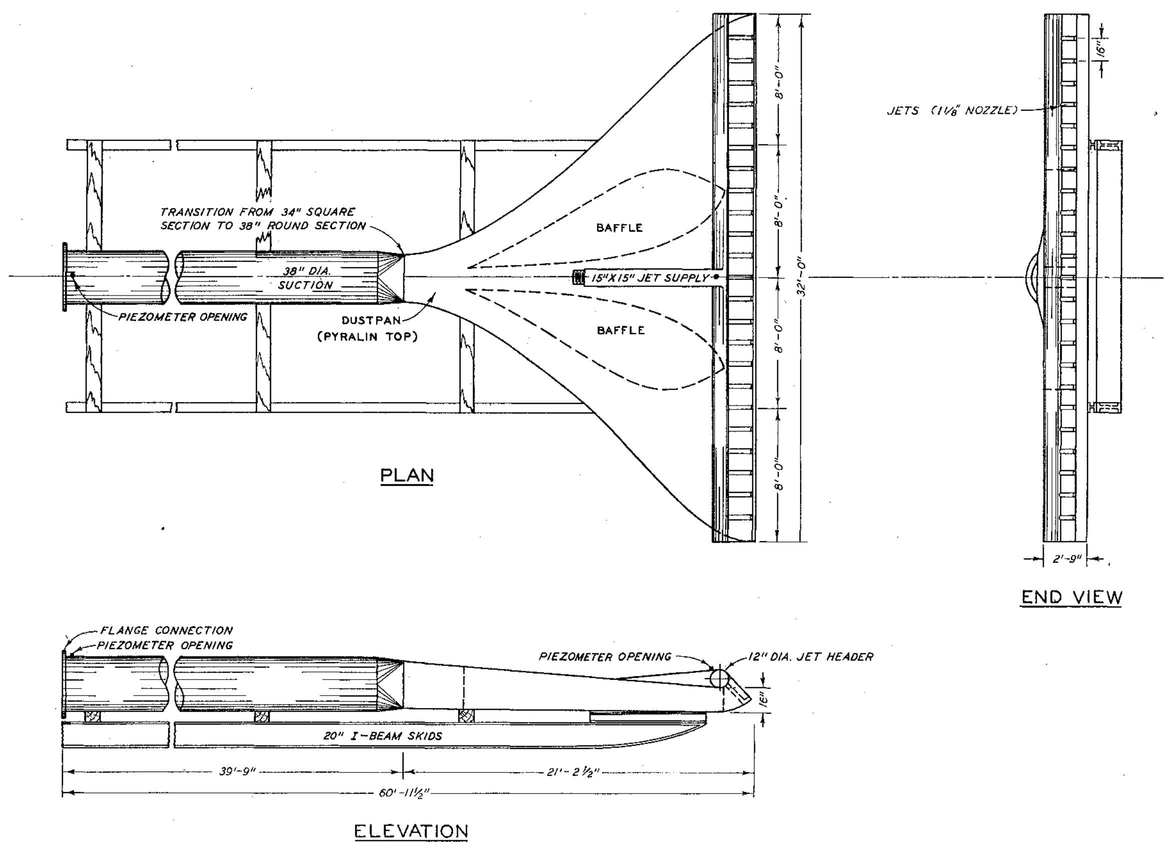

Fig. 10

Dimensions and details of the flared-wall single-dustpan suction head consisted in realigning the baffles to provide water passages with effective entrance areas of 30, 40, and 30 per cent of the total entrance area, the larger passage being in the middle. Another alteration to this head involved enlarging the diameter of the 23 jets sufficiently so that the quantity of water delivered by these 23 jets was equal to that delivered by the 34 jets on the original double head.

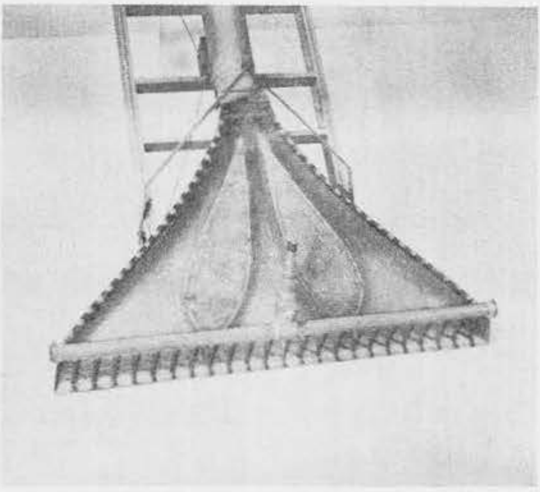

Fig. 11

Flared-wall single-dustpan suction head as tested in the model

Straight-line double-dustpan head

28. The changes in design of the original double head to produce the straight-line design can readily be seen in fig. 12 and 13. All of the design features of the original double head are retained except the flare in the side walls of the dustpans. Elimination of the flared walls would result in considerable economy of fabrication, thus favoring adoption of the straight-line design for future construction, provided the latter showed a comparable efficiency. (As described in paragraph 66, such a modification has been adopted for prototype construction.) A major alteration was made to this head, as shown in fig. 14, in which alignment of the side walls and suction lines was changed in order to afford a straight passage for accelerated movement of dredged material along the outer edges of the dustpans. The altered head was tested both with and without the baffles shown in the photograph.

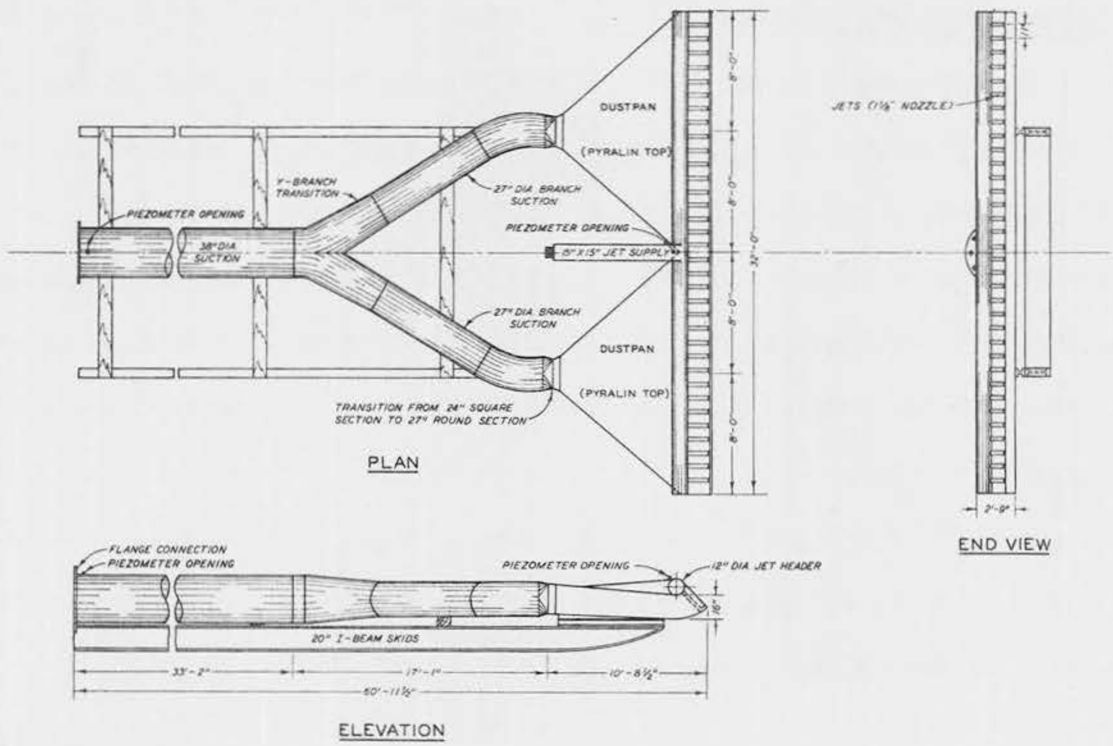

Fig. 12

Dimensions and details of the straight-line double-dustpan suction head

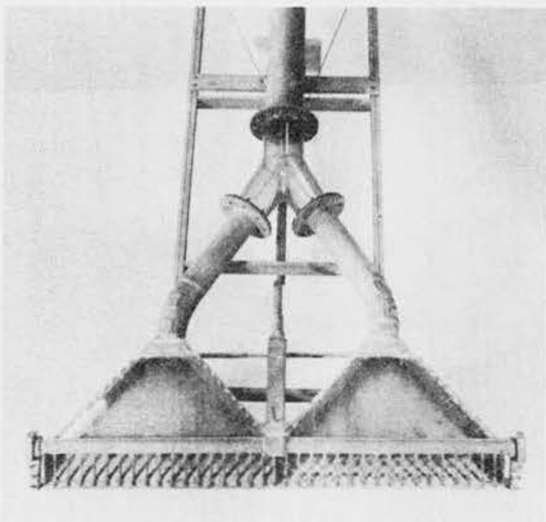

Fig. 13

Straight-line double-dustpan suction head as tested in the model (later constructed for the prototype)

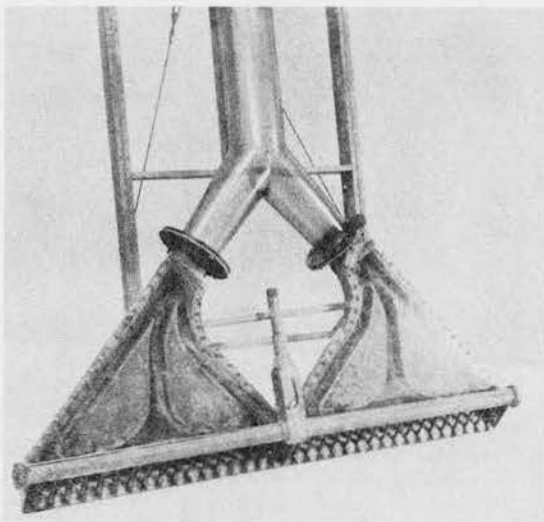

Fig. 14

Straight-line double-dustpan suction head after alterations

Straight-line single-dustpan head

29. The outline of the straight-line single head (fig. 15 and 16) is similar, except in regard to size, to the outline of one dustpan of the unaltered straight-line double-dustpan head described in paragraph 28. Two diamond-shaped baffles in the head divide it into water passages having 37.5 per cent, 25 per cent, and 37.5 per cent of the width at the entrance to the head, respectively. This head was constructed and tested with a raised floor only. Although there were only 24 jets on this head, the size of the jet nozzles was increased until the quantity of jet water delivered by the 24 jets was equal to the quantity delivered by the regular 34-jet design at a pressure of 10 psi.

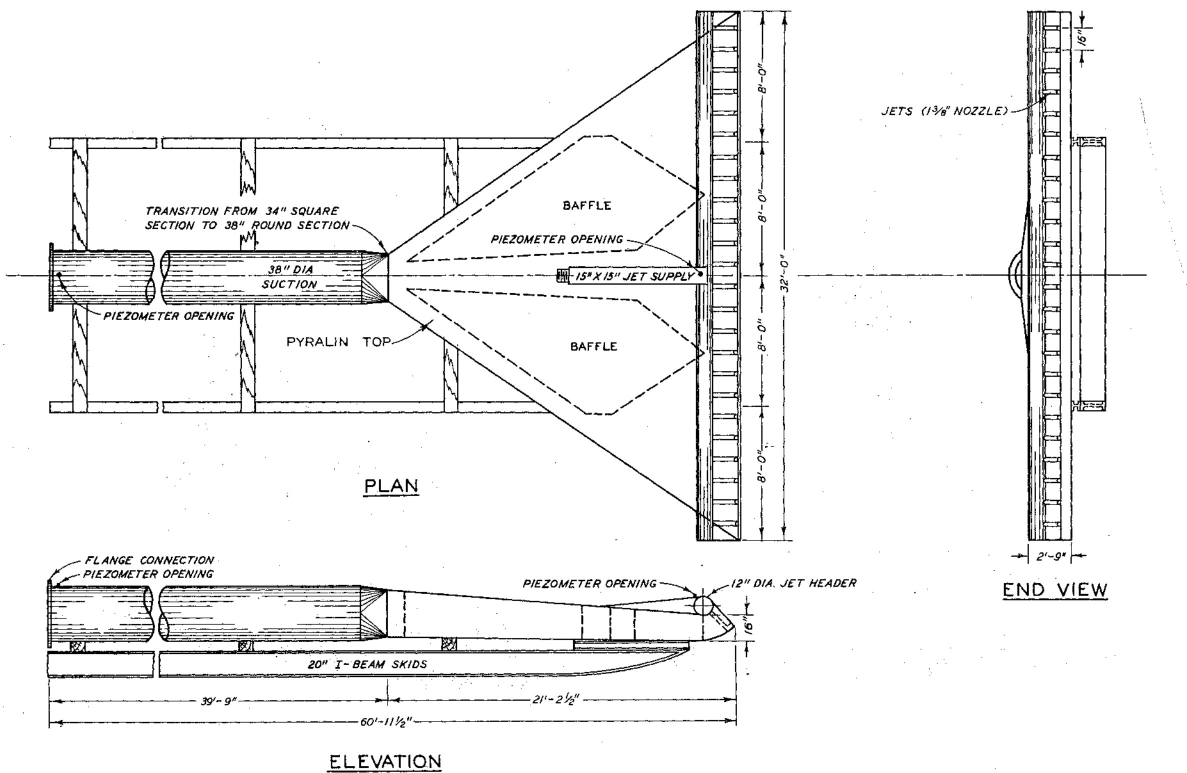

Fig. 15

Dimensions and details of the straight-line single-dustpan suction head

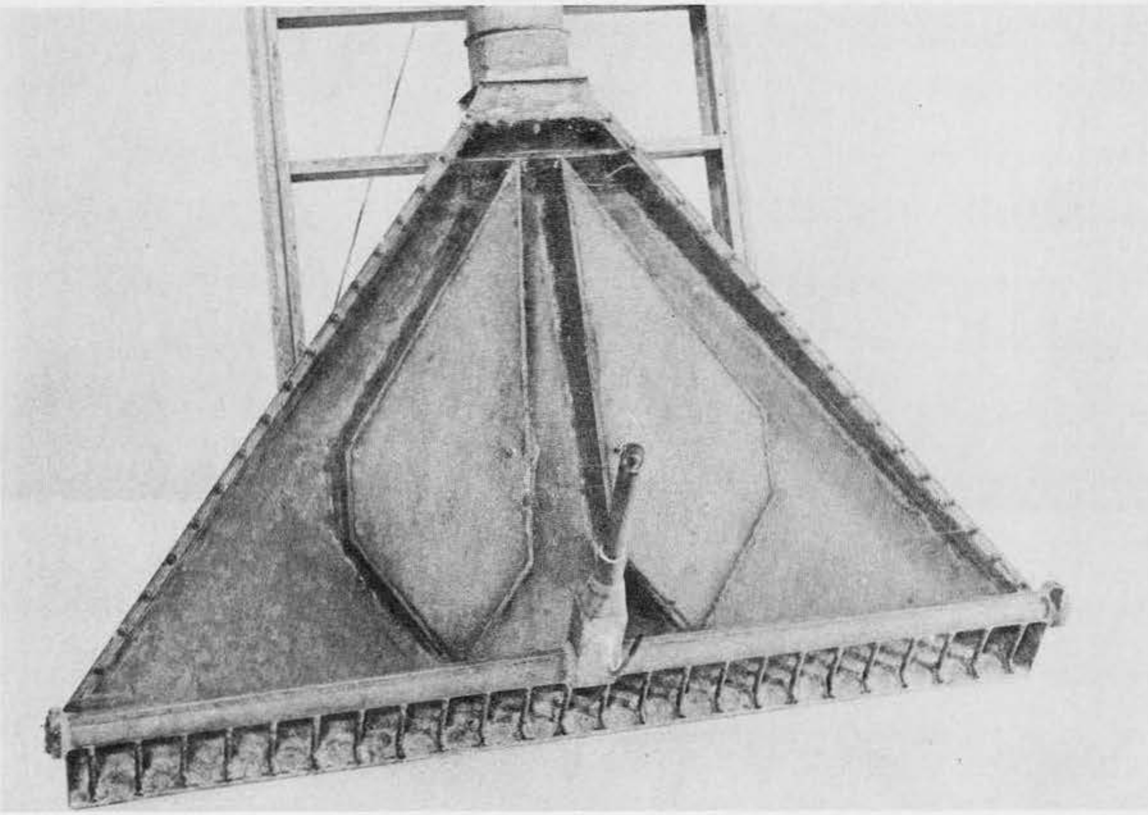

Fig. 16

Straight-line single-dustpan suction head as tested in the model

Features Tested

30. Most of the features tested have been enumerated in the descriptions of the various dredge heads tested, or elsewhere in the preceding text. Additional features studied, though not heretofore discussed in detail, included the effect of jet spacing, the effect of end jets, the effect of rounding the nose of the dredge head, and the distribution of velocities within the suction head. The following paragraphs describe the manner of accomplishing the studies just listed, and summarize all features tested in investigating relative efficiencies and efficacy of design of the various dredge heads.

31. The effect of jet spacing was determined simply by plugging alternate jets or, as in one case, two out of every three jets. The effect of end jets was studied both by the addition of single large jets, similar to those occasionally employed in the prototype, and by development of new end jets based on model observations. The prototype design of end jet is shown in fig. 17, and consisted of a single 4-in. jet attached to each end of the jet header, turned outward at an angle of 20 degrees with the longitudinal axis of the jet header. These jets could also be positioned so as to direct streams at any desired angle in a vertical plane. The new design of end jets consisted, as shown in fig. 18, of three 1.5-in. jet nozzles mounted one above the other in a waterbox attached to each end of the regular jet header. The waterbox extended downward along the end walls of the suction head and was supplied

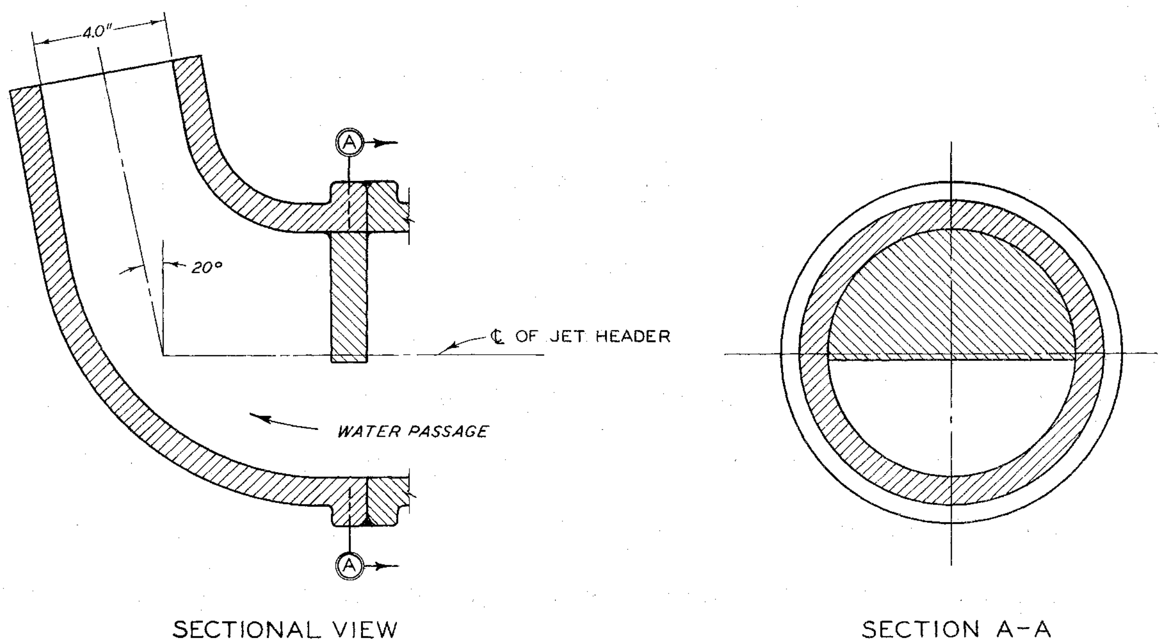

Fig. 17

Prototype end jet tested on the model

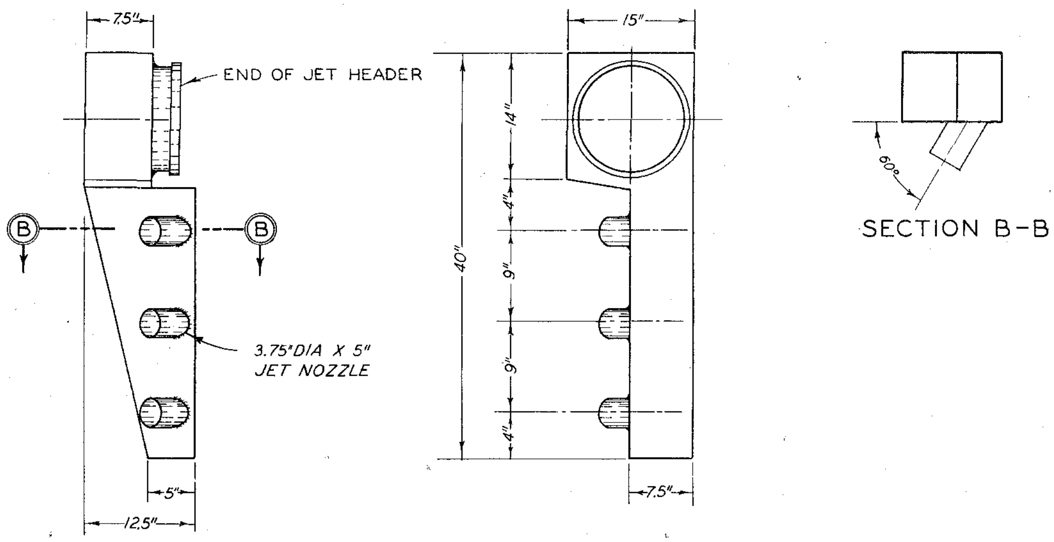

Fig. 18

New type end jet developed from the model study

from the regular jet header. The nozzles were set to project a stream of water at an angle of 30 degrees outward from the centerline of the cut and at an angle of 25 degrees above a horizontal plane.

32. Examination of the shape of the breast of numerous dredge cuts indicated the possibility of making an advantageous change in the shape of the cutting edge of the dredge head; more favorable performance was expected from a head with a rounded front. Accordingly, as a first step

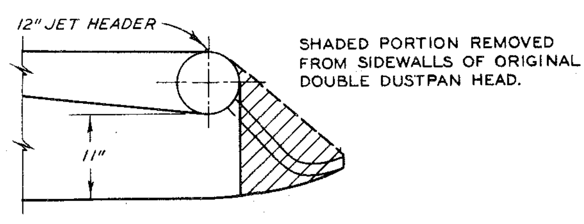

Fig. 19

Rounded nose design of suction head formed by removing portion of sidewalls

toward determining what gain might be realized from such a design, the nose of the original double-dustpan head was altered as shown in fig. 19 by removing the straight portion of the side wall extending beyond the jet header. Much more radical alternate designs were considered, but were not developed in view of other model results.

33. Distribution of velocities in the suction head was determined by means of a ball-type pitot tube arranged for insertion into the head through corporation cocks installed on several traverse lines in the pyralin top of the dredge head; the equipment for making these tests is shown in fig. 20. The protractor was attached to the top of the corporation cock in order that the direction of maximum velocity with respect to the centerline of the suction head could readily be determined. Velocity magnitudes were determined from the manometer readings in accordance with previous calibrations of the pitot tube.

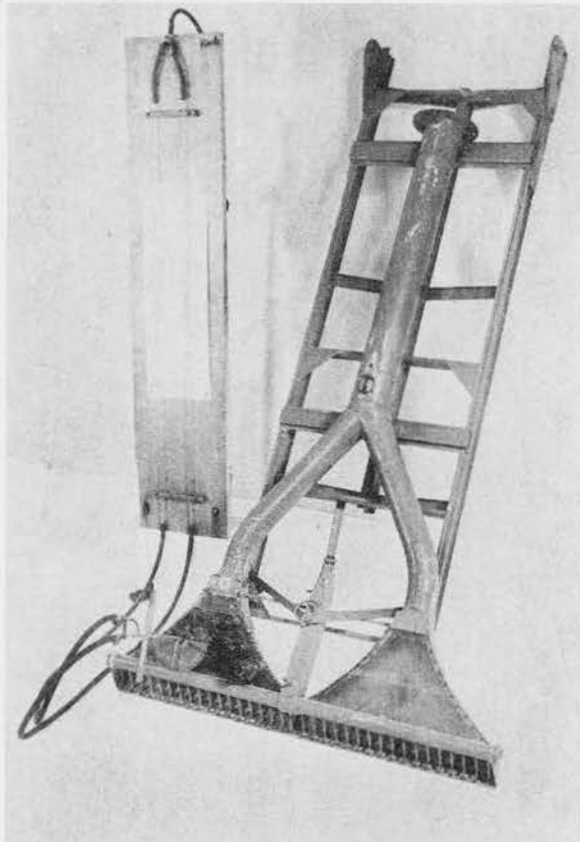

Fig. 20

Apparatus used for determining velocities in the suction head

34. To summarize the various features tested and to indicate the scope of the tests, since many features were not completely investigated due to obvious lack of merit in the initial stages of investigation, the following tabulation has been prepared:

Type of Head

		Original Double	Remodeled Double	Single	Straight Line Double	Altered St.Line Double	Straight Line Single
Ratio of areas of suction opening and suction pipe	3.03:1	–	x	–	–	–	–
	3.72:1	x	–	x	x	x	–
	4.04:1	–	x	–	x	–	x
	5.08:1	–	x	x	–	–	–
Raised center floor		–	x	–	x	x	x
Jet pressure		x	x	x	x	x	x
Jet spacing		–	–	x	x	–	–
Jet water		–	–	x	–	–	–
End jets -- orig.		x	x	–	–	–	–
End jets -- new		–	–	–	x	x	x
Rounded nose		x	–	–	–	–	–
Velocity traverse		x	–	–	–	–	–
Baffles in head		–	–	x	–	x	x
Baffles in Y-branch		–	x	–	–	–	–
Baffles in lines		–	x	–	–	–	–
Rate of advance		x	x	–	x	x	x

Chronology of Tests

35. It is considered impractical to present a chronological description of the various tests; in this case, moreover, there would be no particular significance to such a presentation. The various heads tested were constructed with ease of interchangeability in mind; this permitted testing of whichever head was properly conditioned from test to test. Thus the study proceeded without regard for completion of any one phase of a time schedule, but rather with the view toward efficiently accomplishing the over-all testing program as outlined in the preceding paragraph. The over-all schedule of tests was quite flexible, with more or less emphasis being given to each feature tested as its relative merit was determined from the initial model observations. Significant observations made during any particular test are reported in the comparative analysis of results presented in the next part of this report.

PART V: COMPARATIVE ANALYSIS OF RESULTS

Basic Considerations

36. The unusual number of interrelated variables considered during the course of this investigation precluded the testing of any one assembly under all possible conditions of operation; careful observation of the model in operation and spot analyses of results were relied on quite liberally in shaping the testing program. Consequently, care must be used in making comparisons, other than those given in the following text of this report, to ensure that all conditions were identical for any two tests being so compared.

37. Tabulations of complete test data, immediately following the text of this report, will be noted to contain an "A" series and a "B" series of tests; this division of data is necessary because the suction pump used for these tests was given an extensive overhauling between the so-called A and B series of tests. Significant changes in the pump characteristics and efficiency were noted subsequent to these repairs, and while readjustments made to the model prior to the B series of tests were considered sufficient for purposes of continued testing, it is not considered advisable to make direct comparisons with tests in the A series. This limitation is considered inconsequential, in that tests on the original dredge head were repeated for comparative purposes before proceeding with the B series of tests. Further distinction may be noted in the A and B series of tests, in that the A series of tests was run at jet pressures of 2.6, 5.2, and 7.8 psi, while the B series of tests was run at jet pressures of 10, 15, and 20 psi.

38. The following paragraphs present typical, though not necessarily comprehensive, comparisons of the relative performances of the several types of dredge heads tested and the effects of a number of alterations in various design features incorporated in the several heads. All of the quantities used are expressed in prototype terms, and the rate of cutting in cu yd per hr is used as an index for the efficiency of the heads. A second standard for comparing the heads, that of finding the speed at which the head blocked, had been contemplated, but was abandoned because in most cases this speed was above the speed at which the carriage could be operated in the model.

Relative Efficiency of Basic Types of Suction Heads

39. On the basis outlined in paragraph 37, the following comparative tables have been prepared for each basic type of suction head tested. Comparisons are made at various jet pressures with a rate of advance of 4 fpm, and at various rates of advance with a jet pressure of 15 psi. Due to the many variables inherent in this type of model study, and over which rigid control could not be exercised, it is recommended that yardage values tabulated below should not be interpreted or compared more closely than to the nearest 50 cu yd per hr.

Original double-dustpan vs flared-wall single-dustpan

40. Comparative results from tests of the original double-dustpan and the flared-wall single-dustpan suction heads are presented in the following tabulation:

Jet Pressure psi	Original Double Head Test No.	Original Double Head Rate of Cutting Cu Yd Per Hr	Single Head Test No.	Single Head Rate of Cutting Cu Yd Per Hr
2.6	17A	3170	25A	3230
5.2	16A	3460	21A	3320
7.8	14A	3690	26A	3510

The poorer showing of the single head at the higher jet pressures is accounted for by the large ratio of suction opening to suction pipe, which was 5.08 to 1 with the 16-in. effective entrance height incorporated in the initial construction of the single head. Tests with an area ratio of 3.72 to 1 in this head are not available except under the conditions of increased jet water (23 original jets enlarged to give discharge equal to 34 jets on double head); however, the change in jet discharge was responsible for only about 100 cu yd per hr increase in yardage output (see paragraph 50), while the over-all gain in yardage with a ratio of 3.72 to 1 was considerably greater than this. The only comparable tests with these heads, both constructed to an area ratio of 3.72 to 1, were made at a jet pressure of 5.2 psi; results of three tests on each head were as follows:

Original Double Head Test No.	Original Double Head Rate of Cutting Cu Yd Per Hr	Single Head Test No.	Single Head Rate of Cutting Cu Yd Per Hr
16A	3460	47A	3560
19A	3580	48A	3580
40A	3510	49A	3500
Ave.	3520	Ave.	3550

These results indicate approximately equal performance from the original double-dustpan head and the flared-wall single-dustpan head under the conditions tested. Observation of the single head in operation showed small eddies in the side passages near the upper ends of the baffles and a streak of clear water in the center of the middle passage. An attempt made to correct this condition by revising the baffles as described in paragraph 27 was not successful; results of this test are presented in the discussion of effectiveness of baffles in paragraph 58.

Original double-dustpan vs remodeled double-dustpan

41. Since the remodeled double-dustpan, incorporating either a flat or raised floor, with an area ratio of 4.04 to 1, is used for comparison with heads tested subsequently, it is desirable to demonstrate the similarity of performance of the original double-dustpan head (ratio 3.72 to 1) to the remodeled double head (ratio 4.04 to 1, flat floor). Typical comparative results were as follows:

	Original Double Head		Remodeled Double Head	
Jet Pressure psi	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
10	6B	3630	35B	3640
15	9B	3670	36B	3700
20	10B	3720	----	----

These data substantiate the similarity of performance between the remodeled and original double-dustpan heads, thus validating use of the remodeled head for further comparisons in cases including flat floors; data presented in paragraph 55 show the negligible effect of a raised floor, thus validating subsequent comparisons of heads with raised floors where data are lacking for flat-floor conditions. Comparative data on the original and remodeled double-dustpan heads at various rates of advance (jet pressure 15 psi) are presented in the following tabulation:

	Original Double Head		Remodeled Double Head	
Forward Speed fpm	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
4	9B	3670	36B	3700
5	23B	4510	38B	4460
6	22B	4960	40B	5240
7	24B	5820	39B	5790

Here again performance was very similar in the two heads; figures for a raised-floor construction are 3740 cu yd per hr at 4 fpm (test 32B) and 4420 cu yd per hr at 5 fpm (test 34B).

Remodeled double-dustpan head vs straight-line double-dustpan head

42. Typical comparative results of tests of the flared-wall double-dustpan suction head and the straight-line double-dustpan head, made with raised floors and area ratios of 4.04 to 1, are as follows:

	Remodeled Double Head		Straight-Line Double Head	
Jet Pressure psi	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
10	31B	3600	45B	3680
15	32B	3740	43B	3740
20	33B	3760	44B	3780

This comparison shows the straight-line design of double head to be equally as efficient as the original flared-wall design. Equally efficient performance is noted as the rate of advance is increased, as is indicated in the following tabulation:

Forward Speed fpm	Remodeled Double Head Test No.	Remodeled Double Head Rate of Cutting Cu Yd Per Hr	Straight-Line Double Head Test No.	Straight-Line Double Head Rate of Cutting Cu Yd Per Hr
4	32B	3740	43B	3740
5	34B	4420	46B	4470
6	---	----	47B	5240
7	---	----	48B	5850

Remodeled double-dustpan head vs altered straight-line double head

43. Few tests were run on the altered straight-line double-dustpan head, as no better results were being obtained than with previously-tested heads of simpler construction. The addition of baffles to the altered straight-line double head gave even poorer results; comparative data are presented in the discussion of effectiveness of baffles in paragraph 59.

Remodeled double-dustpan head vs straight-line single head

44. Testing of the straight-line single-dustpan suction head showed its performance to be less efficient than the original double head (or the straight-line double head); comparative results under the same conditions as just considered for the straight-line double head are as follows:

Jet Pressure psi	Remodeled Double Head Test No.	Remodeled Double Head Rate of Cutting Cu Yd Per Hr	Straight-Line Single Head Test No.	Straight-Line Single Head Rate of Cutting Cu Yd Per Hr
10	31B	3600	----	----
15	32B	3740	100B	3550
20	33B	3760	105B	3600

Further indication of the inefficiency of this head was obtained in test 101B, rate of advance 5 fpm, in which the outside passages of the head choked up rapidly.

Effect of Varying Rate of Advance

45. The rate of advance is herewith discussed generally without comparing specific tests to any further extent than has already been done in some of the preceding comparative tables. The speed was not great enough in most cases to cause blocking of the head and, therefore, a complete comparison cannot be made between tests. All of the tests that were made with a speed greater than 4 fpm had a jet pressure of 15 psi. As the speed was raised, the cross section of the cut became less; fig. 21, plotted from data obtained during tests of the straight-line double head, typifies this relation. This decrease in cross-sectional area occurred because of the inability of the suction head to remove material that fell into the cut from the side slopes; this material banked up on

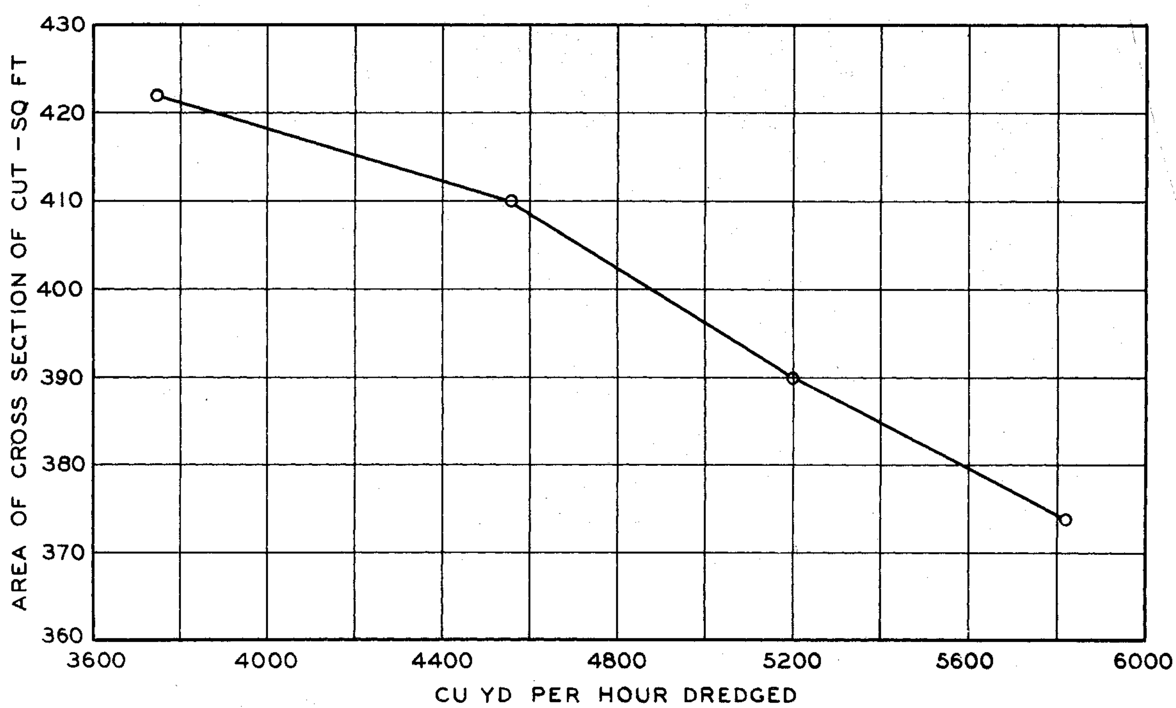

Fig. 21

Relation of quantity of material dredged to area of cross section of cut the sidewalls at the ends of the suction head or, at the highest speeds, piled over the ends of the jet header and fell back into the cut behind the suction head. Thus, in all cases the higher speeds produced a higher rate of cutting, but at the cost of a smaller cross section. The most economical speed could not be determined from the model study, as many factors concerning the particular work on which the dredge was engaged were not known.

Effectiveness of Jets and End Jets

Effects of variations in jet pressure

46. The effects of variations in jet pressure have been covered in previous tabulations. To summarize these effects, it can be stated that in the A series of tests utilizing jet pressures of 2.6, 5.2, and 7.8 psi, there was an increase in output consistent with increase in jet pressure with the exception of those situations in which some other condition decreased ability of the head to function efficiently; while in the B series of tests utilizing jet pressures of 10, 15, and 20 psi there was an appreciable increase in yardage output when the pressure was raised from 10 to 15 psi, but only a slight further increase when the pressure was raised from 15 to 20 psi. It appears, therefore, that an optimum jet pressure is in the vicinity of 15 psi.

Effects of jet spacing

47. This factor is more or less interrelated with quantity of jet water, in that tests with altered jet spacings were made without manipulation of the quantity of jet water, which naturally varied somewhat as

the number of jets in operation was changed. This variable was isolated in one instance, however, as described in paragraph 50, wherein the size of the jets was altered to change the quantity of jet water without any change in jet spacing.

48. In testing the flared-wall single-dustpan head, one test was made in which every other one of the 23 original jets was closed, leaving only 12 jets open. Results of this test, conducted at a jet pressure of 5.2 psi, were as follows:

Test No.	Jets Open	Rate of Cutting Cu Yd Per Hr
21A	23	3320
23A	12	2750

49. More extensive tests of the effect of jet spacing were conducted on the straight-line double-dustpan head. The nominal jet spacing of 11 in. was altered to 22 in. by closing every other jet, and to 33 in. by closing two of every three jets. The tests were made at jet pressures of 15 and 20 psi with a forward speed of 4 fpm, with the following results:

	15 psi Jet Pr		20 psi Jet Pr	
Jet Spacing In.	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
11	56B	3750	57B	3740
22	64B	3630	65B	3630
33	73B	3470	74B	3560

These results show that jet spacings of 22 in. and 33 in. are progressively less effective than the 11-in. spacing.

Effect of quantity of jet water

50. In testing the flared-wall single-dustpan head, it appeared that the lower efficiency as compared with performance of the original double-dustpan head was occasioned in part by the lesser quantity of jet water discharged by the 23 jets on the single head as compared to the 34 jets on the double head. Accordingly, the 23 jets were enlarged to provide for a quantity of jet water equal to the discharge of the 34 jets on the double head; results were as follows for this alteration:

Size of Jets	Test No.	Rate of Cutting Cu Yd Per Hr
Original	21A	3320
Enlarged	41A	3410

Enlarging the jets to provide increased discharge of jet water resulted in an increase of 90 cu yd per hr dredged.

Effects of end jets

51. End jets tested on the original double-dustpan head, consisting of one 4-in. diameter jet mounted on each end of the jet header, gave results as follows:

	No End Jets		End Jets	
Jet Pressure psi	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
5.2	*	3520	18A	3580
7.8	14A	3690	15A	3190

* Average of tests 16A, 19A, and 40A

Only a slight advantage was noted at 5.2 psi jet pressure, and a serious reduction in performance occurred at a jet pressure of 7.8 psi; however, model observations indicated that the jets had a marked advantageous effect by virtue of the greater quantity of material loosened in front of the dredge head. The relative ineffectiveness of the end jets at 7.8 psi jet pressure is attributable to material from the side slopes of the cut being washed around the ends of the head and into the cut behind the dustpan. It was believed that adjustment of the vertical angle of these jets would assist in diverting more of the loosened material into the head, and this conclusion was substantiated in later tests.

52. End jets were tested again on the remodeled double-dustpan head with particular attention given to the effects of adjusting the vertical angle; results of these tests, made at a jet pressure 15 psi and forward speed of 4 fpm, were as follows:

Single 4-In. End Jets	Test No.	Rate of Cutting Cu Yd Per Hr
Not Installed	36B	3700
Installed, Position 1	41B	3810
Installed, Position 2	42B	3950

In position 1 the end jets were set to discharge at an angle of 25 degrees above a horizontal plane, while in position 2 the end jets were set to discharge at an angle of 20 degrees below a horizontal plane. On the basis of these tests and corresponding model observations, a new-type end jet was designed with the primary function of reducing steepness of the side slopes in the cut; this jet was constructed as illustrated in fig. 18.

53. The new-type end jets were tested on the straight-line double-dustpan head. Results with respect to jet pressure at a speed of 4 fpm were as follows:

Jet Pressure psi	No End Jets Test No.	No End Jets Rate of Cutting Cu Yd Per Hr	End Jets Test No.	End Jets Rate of Cutting Cu Yd Per Hr
10	55B	3730	---	----
15	56B	3750	68B	3970
20	57B	3740	72B	3970

Although these yardage values are not much greater than those obtained with the original end jets, observation of the model showed the new-type end jets to be much more effective in reducing the steepness of the side slopes and in producing a smoother cut. Results with respect to rate of advance were very satisfactory, as shown in the following tabulation:

Forward Speed fpm	No End Jets Test No.	No End Jets Rate of Cutting Cu Yd Per Hr	End Jets Test No.	End Jets Rate of Cutting Cu Yd Per Hr
4	56B	3750	68B	3970
5	58B	4560	69B	4910
6	59B	5200	70B	5660
7	60B	5820	71B	5940

The new-type end jets were equally efficient in maintaining high yardage output even with decreased jet water; thus, a comparison of values obtained in testing the straight-line double head with every other jet closed off shows the following results:

Jet Pressure psi	No End Jets Test No.	No End Jets Rate of Cutting Cu Yd Per Hr	End Jets Test No.	End Jets Rate of Cutting Cu Yd Per Hr
15	64B	3630	66B	3880
20	65B	3630	67B	3970

Another consideration which further illustrates the effectiveness of the new-type end jets is in respect to the area of cross section of the dredged cut secured; fig. 22 shows how an appreciable gain in rate of dredging can be effected with only slight loss in cross-sectional area, which is quite different from the condition existing when dredging without these end jets.

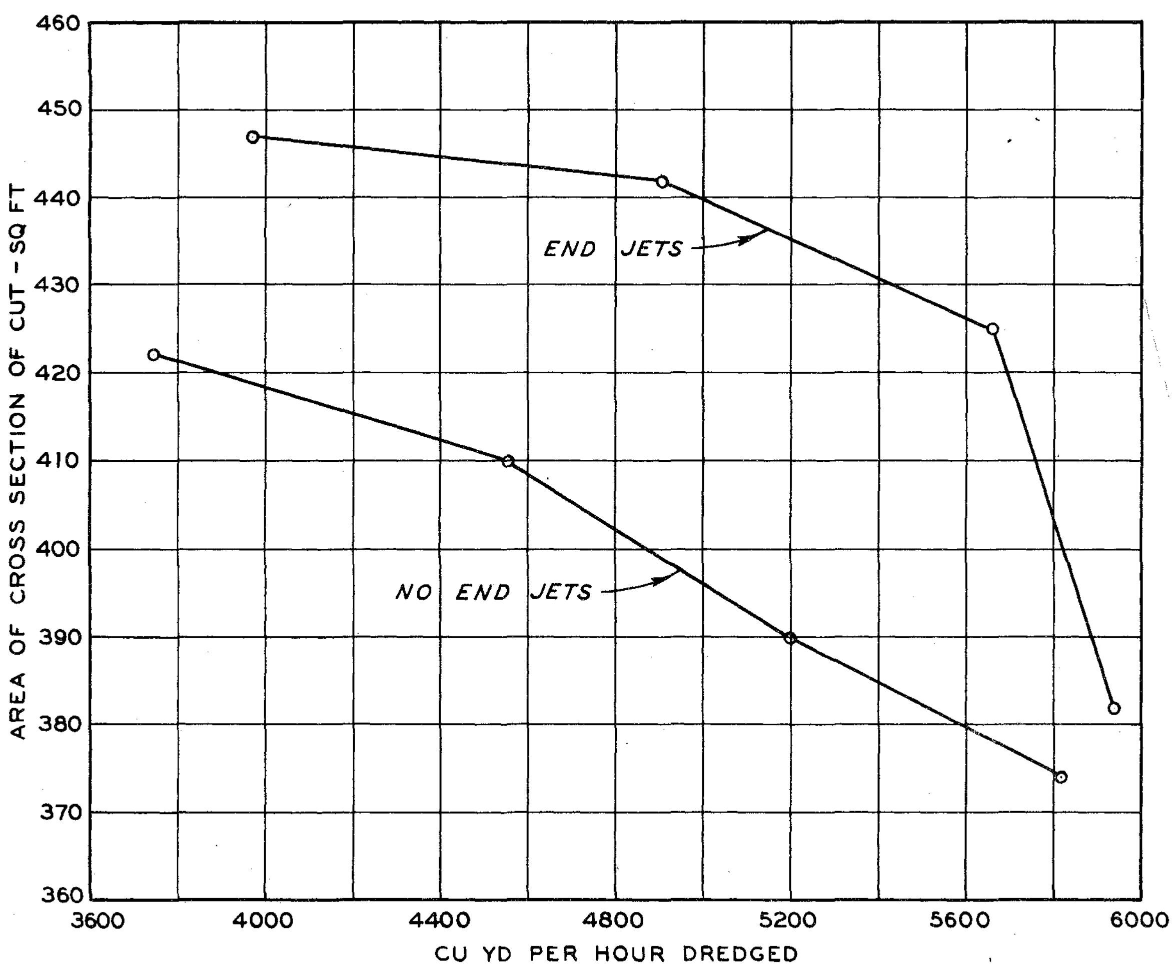

Fig. 22

Effect of end jets on quantity of material dredged

Effect of Height of Opening

54. A number of conditions were tested in which one factor under investigation was the effect of changes in the critical controlling height of opening into the suction head; this variable is of significance because of its relation to velocity imparted to material passing through the head. True weight is given to the effect of varying this dimension by computing the effective cross-sectional area of entrance to the head corresponding to the controlling height, and by expressing this area as a ratio with respect to area of the suction pipe; this computation was illustrated in paragraph 24. Typical data recorded for the flared-wall single-dustpan head are as follows:

Ratio of Openings	Test No.	Rate of Cutting Cu Yd Per Hr
3.72 to 1	*	3550
5.08 to 1	21A	3320

* Average of tests 47A, 48A, and 49A

Similar data recorded for the original and remodeled double-dustpan head are as follow:

	Jet Pr 10 psi		Jet Pr 15 psi		Jet Pr 20 psi	
Ratio of Openings	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
3.03 to 1	51B	3610	49B	3700	50B	3730
3.72 to 1	6B	3630	9B	3670	10B	3720
4.04 to 1	35B	3640	36B	3700	33B	3760
5.08 to 1	25B	3560	26B	3710	27B	3710

Other comparisons show about the same relative results; model observations indicate that the ratio of 5.08 to 1 is rather high (note that the yardage falls off in the above tabulation at a jet pressure of 10 psi) and that a ratio of not greater than 4.04 to 1 should probably be considered nearer optimum for reliable results.

Flat Floor vs Raised Floor

55. The raised floor was created as shown in fig. 9, paragraph 26, by raising a portion of the center section of the floor above the bottom of the dustpan, with a sloping floor from each side of the center section to the walls of the dustpan. Results of tests of a raised floor installed in the remodeled double-dustpan head are compared in the following tabulation with results obtained from tests with a flat floor spaced to give an equivalent effective entrance area:

		Flat Floor		Raised Floor	
Jet Pressure psi	Forward Speed fpm	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
10	4	35B	3640	31B	3600
15	4	36B	3700	32B	3740
15	5	38B	4460	34B	4420

As indicated from the results tabulated above, the raised- and flat-floor designs gave essentially the same results, and observations of the model in operation during these tests failed to show any advantageous features in the raised-floor design.

Effect of Rounding Nose

56. The original double-dustpan head was altered as shown in fig. 19, paragraph 32, by removing a portion of the sidewalls at the end of

the jet header. Results obtained with this alteration effected are compared with basic results at a jet pressure of 5.2 psi in the following tabulation:

Original Construction		Altered Construction	
Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
16A	3460	50A	3420
19A	3580	52A	3470
40A	3510	53A	3560
Ave.	3520	Ave.	3480

Observation of the model in operation indicated that this alteration was insignificant with respect to the results obtained under the two conditions.

Effects of Baffles

57. A number of tests were conducted involving determination of the effects of baffles. These tests included a study of spacing and arrangement of baffles in the dustpan proper, as well as the effects of baffles in the suction lines and in the Y-branch. Typical arrangements tested and comparative results secured are discussed in the following paragraphs.

Baffles in dustpans

58. The flared-wall single-dustpan head as initially constructed contained baffles to divide the three entrance passages into equal areas. During tests on this head it was observed that the middle passage contained a streak of clear water; on this basis, an altered construction was tested with the baffle spacing changed to provide water passages with

entrance areas of 30, 40, and 30 per cent of the total entrance areas, the larger passage being in the center. Comparative results of tests made with the original and revised baffle spacing are as follows:

	Original Baffles		Revised Baffles	
Jet Pressure psi	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
5.2	21A	3320	30A	3330
7.8	26A	3510	33A	3420

Model observations bore out the ineffectiveness of the revised baffle spacing in that a wider streak of clear water appeared in the middle passage and the eddies were of greater magnitude in the side passages than when the original baffles were used. This test indicated that the change in the areas of passage opening was in the wrong direction; that is, the areas of the side passage openings should have been made larger and the area of the center passage opening made smaller. A supplementary test was made with the baffles removed entirely from the head; this test definitely showed that baffles were necessary for the proper operation of the single head, as illustrated in the following tabulation:

Baffles In Dustpan	Test No.	Rate of Cutting Cu Yd Per Hr
Original	41A	3400
Revised	36A	3400
None	42A	3100

The head clogged so badly during test 42A that, at the end of the run, approximately only one-third of the entrance was open.

59. Baffles were tested in the dustpans of the altered straight-line double-dustpan head, described in paragraph 28, for the purpose of

reducing the area of the total water passage in order to increase acceleration of the material passing through the head, and to give proper direction of flow to the water at its entrance into the suction line. Due to lack of complete comparative data for the altered head without baffles (these data were not secured because of the poor performance of the altered head without baffles), the following tabulation contains comparative values for the unaltered straight-line double head as well as for the altered head with and without baffles:

	Unaltered Head		Altered Head		Altered Head With Baffles	
Jet Pressure psi	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
10	55B	3730	----	-----	107B	3420
15	56B	3750	95B	3640	109B	3540
20	57B	3740	----	-----	110B	3560

Similar data at a jet pressure of 15 psi and a varying rate of advance are as follows:

	Unaltered Head		Altered Head		Altered Head With Baffles	
Forward Speed fpm	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
4	56B	3750	95B	3640	109B	3540
5	58B	4560	94B	4360	108B	4180
6	59B	5200	----	-----	112B	4710
7	60B	5820	----	-----	-----	-----

It is probable that additional friction, induced by placing the baffles in the head, was primarily responsible for the reduction in yardage.

Baffles in suction lines

60. In observing the action of the dredged material in the pyralin Y-branches of both the remodeled and the straight-line double heads, it was noted that there were spaces in the suction lines along the outside walls in which no sand was being transported; these void spaces existed principally in the 27-in. lines just below their junction with the 38-in. line. Sheet-metal baffles were placed in the curved portion of each 27-in. suction line of the remodeled double head in an effort to eliminate the void spaces. The baffles, extending throughout the curved portion of the 27-in. lines, were made to divide the pipe into quadrants; the ends were fastened to the top, bottom, and midpoints of the two sides. Data are given in the following table for tests made with and without the baffles installed:

		No Baffles			Baffles Installed		
Jet Pressure psi	Speed fpm	Test No.	Suction Vacuum In. Hg	Rate of Cutting Cu Yd Per Hr	Test No.	Suction Vacuum In. Hg	Rate of Cutting Cu Yd Per Hr
10	4	51B	18.1	3610	61B	21.4	3630
15	5	52B	19.7	4520	63B	24.7	4300
15	7	54B	22.8	5820	62B	28.8	5570

Although the baffles had a negligible effect on the rate of cutting for a speed of 4 fpm at a 10 psi jet pressure, there is a considerable increase in the suction vacuum. As the speed was increased above 4 fpm, the rate of cutting for the tests made with the baffles installed drops appreciably below corresponding tests made without baffles, while the suction vacuum continued to increase with increased rate of advance.

Baffles in Y-branch

61. A straight baffle was placed in the Y-branch to form a wall or shield at the intersection of the inner walls of the 27-in. suction pipes with the 38-in. pipe, extending for 40 in. along the 38-in. suction line. The purpose of this baffle was to reduce turbulence caused by impinging streams from the two 27-in. lines. Results of tests made with this baffle incorporated while testing the remodeled double-dustpan head are compared to basic tests on this head in the following tabulation:

		No Baffle		Baffle Installed	
Jet Pressure psi	Forward Speed fpm	Test No.	Rate of Cutting Cu Yd Per Hr	Test No.	Rate of Cutting Cu Yd Per Hr
15	4	49B	3700	83B	3690
20	4	50B	3730	78B	3690
15	5	52B	4520	84B	4480

As a reduced yardage output prevailed with the baffles in place, and as observation of the model in operation showed negligible reduction in the void areas at the junction of the Y-branch, further testing of baffles in the Y-branch was abandoned.

Velocity Tests

62. For the purpose of determining velocity distribution within the suction head, measurements of velocities were made in one-half of the double-dustpan head by the method described in paragraph 33. Initially, measurements were made at five points in the head, while in a later test the number of points of measurement was increased from 5 to 12. These velocity measurements were taken with the model pumping clear

water and with the jet pump inoperative. Basic data from all measurements have been combined in fig. 23 to show the point at which each velocity reading was taken, the maximum velocity measured at each point, and the direction of maximum velocity at each point. These data have been replotted in fig. 24 to show the uniformity of acceleration imparted to material passing through the head. Replotted as a velocity traverse, the data appear as shown in fig. 25, wherein it will be noted that the velocities in

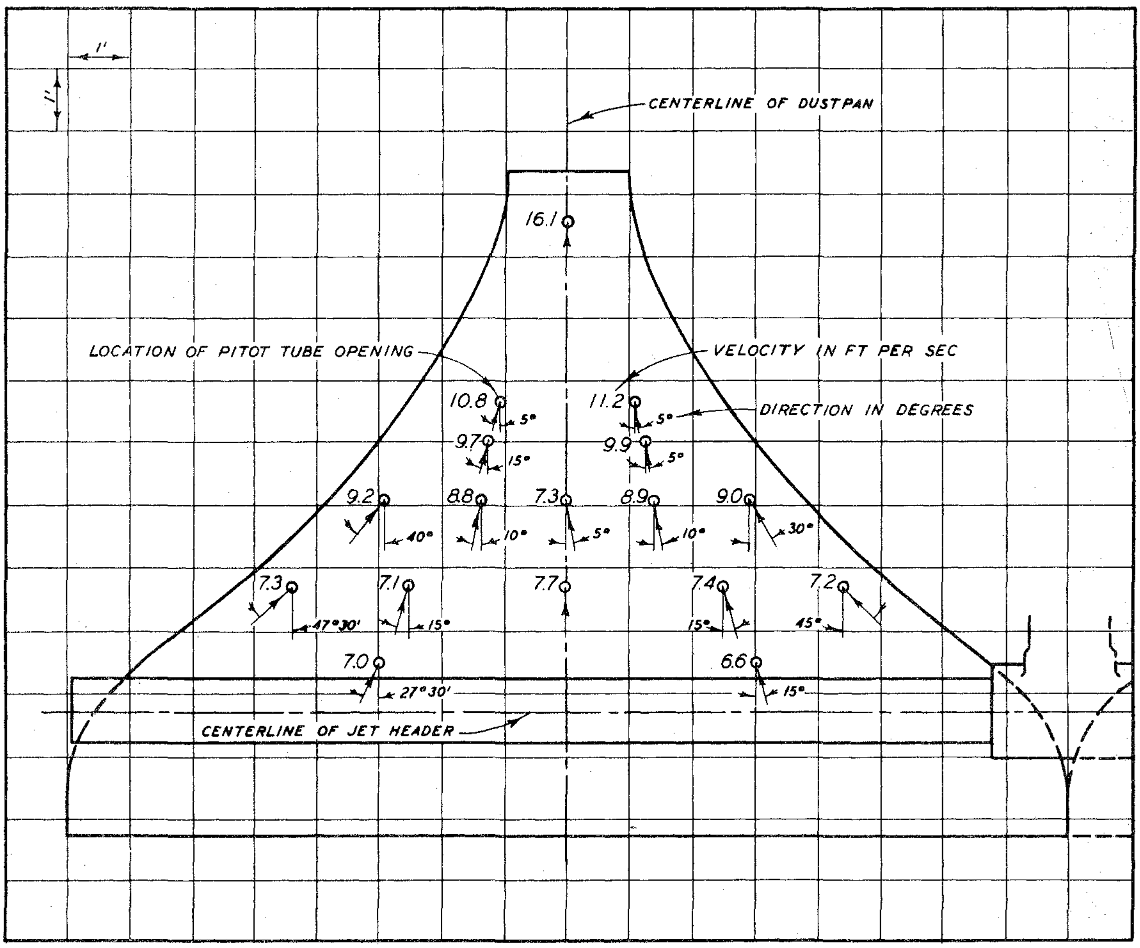

Fig. 23

Amplitude and direction of velocities
in one-half of double-dustpan suction head

the wing sections and in the center section are very nearly the same. These tests served to show that clogging of the outer wing sections of the head was caused by the greater proportion of material that these sections have to carry, rather than by an initial low velocity in the outer wing sections of the head.

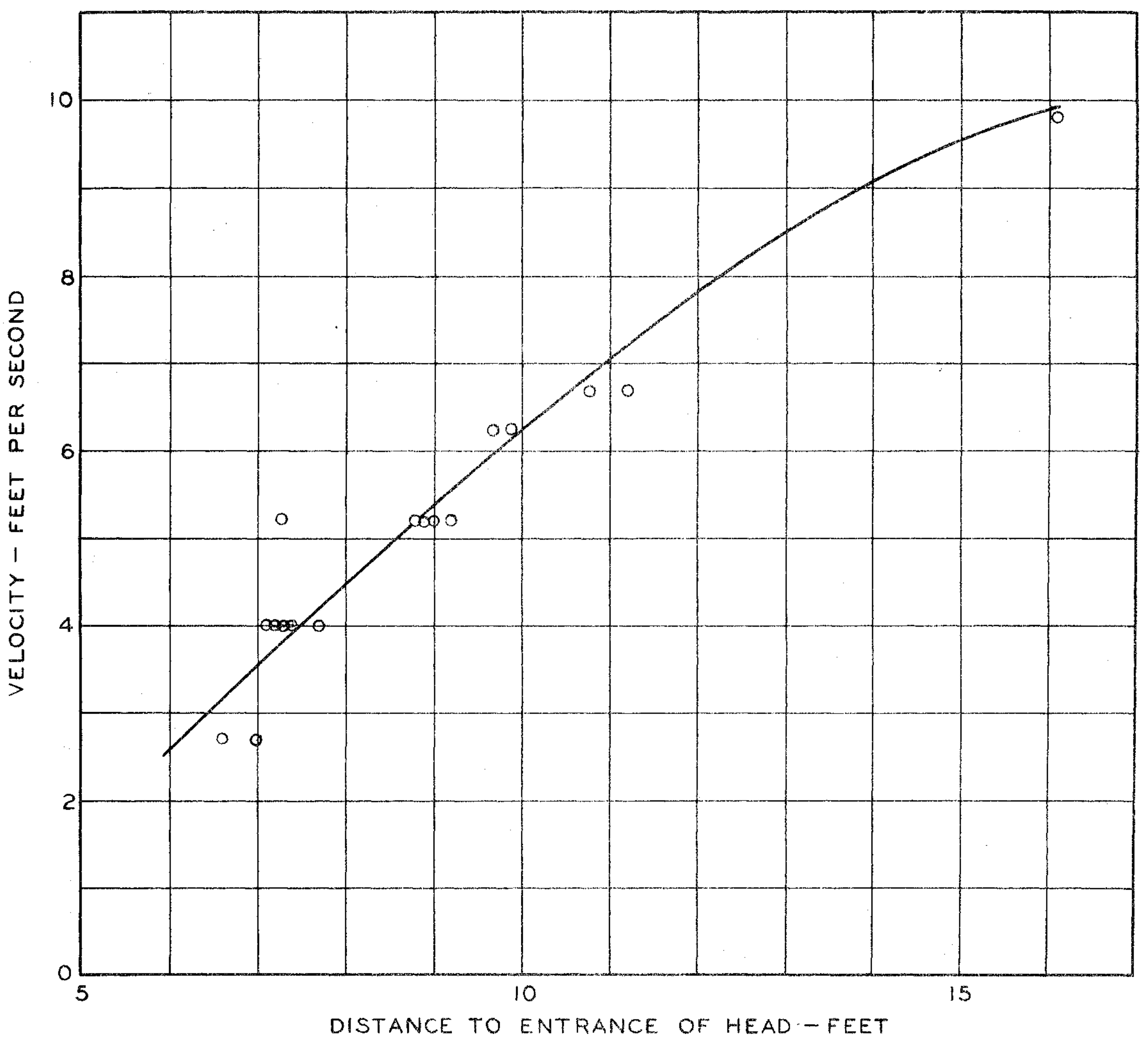

Fig. 24

Distribution of velocities
along length of the double-dustpan suction head

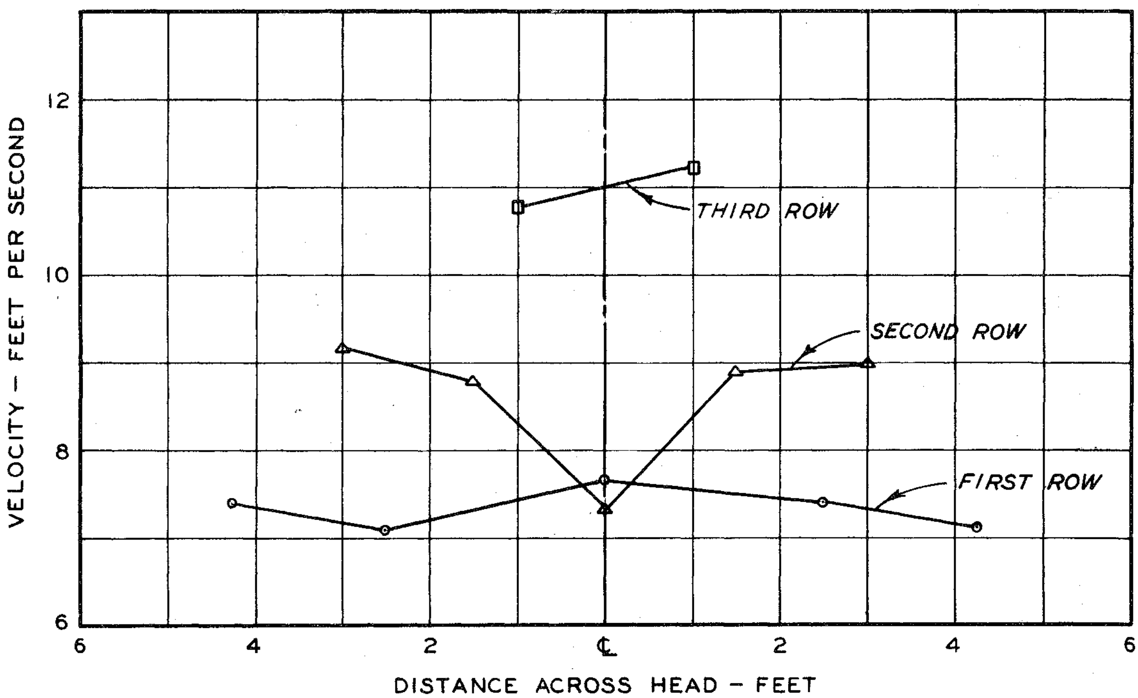

Fig. 25

Distribution of velocities across the
width of one-half of the double-dustpan suction head

PART VI: CONCLUSIONS AND APPLICATION

Review of Results

63. The following tabulation, consisting of a summary of the results presented in the preceding comparative analysis of tests, will provide an over-all basis for the conclusions which follow.

Feature Tested	Results
Original double-dustpan head	(Used as basis of comparison)
Remodeled double-dustpan head	Performance comparable to original double head
Flared-wall single-dustpan head	Performance comparable to original double head
Straight-line double-dustpan head	Performance comparable to original double head
Altered straight-line double-dustpan head	Performance slightly less efficient than original head
Straight-line single-dustpan head	Performance less efficient than original head
Jet pressures 2.6, 5.2, 7.8 psi	Best results at 7.8 psi
Jet pressures 10, 15, 20 psi	With an otherwise efficient head, good yardage increase at 15 psi compared to 10 psi; little further increase at 20 psi
Jet spacing	Efficiency decreases as jets are spaced more than 11 in. apart
Jet water	Efficiency drops as quantity of water is lowered from original head conditions
End jets - original design	Increased efficiency possible using end jets; affected by vertical angle
End jets - new design	Very advantageous results secured, both in yardage output and in area of cross section of cut

Features Tested	Results
Baffles in head	Poor baffle arrangement tends to lower efficiency; best baffle alignment dependent on other factors
Baffles in Y-branch	To the extent tested, results were detrimental rather than advantageous
Baffles in suction lines	To the extent tested, results were detrimental rather than advantageous
Rate of advance	Critical value could not be determined; closely related to many other factors
Height of opening in head	Ratio of 5.08 to 1 (16-in. height in head tested) should be considered with caution; ratios 4.04 to 1 and below were apparently satisfactory
Raised center floor	No effect on results could be determined from this variable

Conclusions

64. The test results indicate that either the flared-wall single-dustpan head or the straight-line double-dustpan head could be constructed with the expectation of performance equal in efficiency to that of the original double-dustpan head, while slightly less efficient results might be secured from a straight-line single-dustpan construction. The use of baffles in the suction lines and in the straight-line double head, and the use of greater jet spacings, decreased the efficiency of the head. It was found that the raised floor design did not increase the efficiency of the heads.

65. Although the tests did not show any one design of head to be outstanding in performance, they did indicate that improvements can be made in the prototype head that will add to its efficiency. The greatest

gain in output in the model head was obtained by the use of the new design of end jets. Use of these end jets gave a flatter side slope to the cut than prevailed when end jets were not used, and thus improved the stability of the cut.

Application

66. Based upon the improved performance of the model head, end jets similar to the new design developed during the model study were fitted on the dredge OCKERSON while it was undergoing repairs, and subsequently to the dredge BURGESS. At the time of this writing a similar alteration is underway on the dredges JADWIN and POTTER. The end jets as tested on the model head are shown by fig. 26, while the corresponding installation on the dredge OCKERSON is shown by fig. 27. The alteration on the dredge BURGESS, eventually scheduled for all other dredges of the Memphis District, is as shown by fig. 28. From comparison of fig. 27 and 28, it may be seen that the jet and trash-rack systems are combined on the latter to form a single unit wherein the jets perform a dual function. Furthermore, the new dustpan for the BURGESS is of the straight-line double-dustpan type, which is more easily constructed than the original flared-wall type, and which model tests

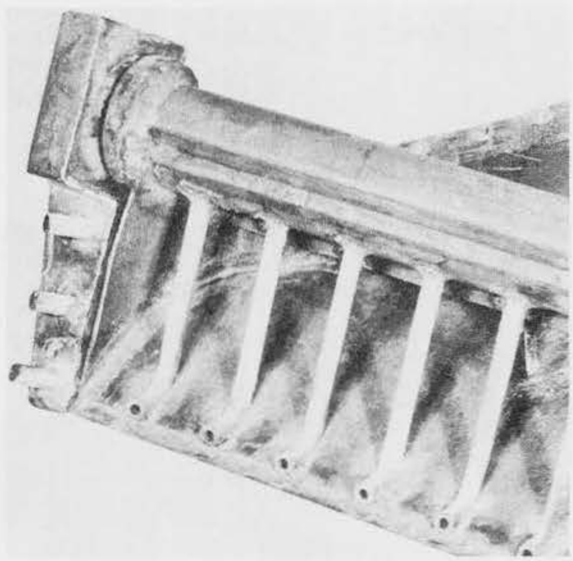

Fig. 26

Model installation of new-type end jets

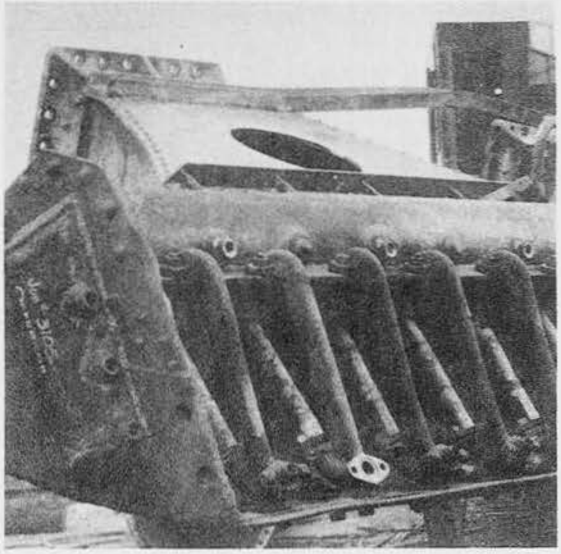

Fig. 27
Prototype installation of
new-type end jets on dredge OCKERSON

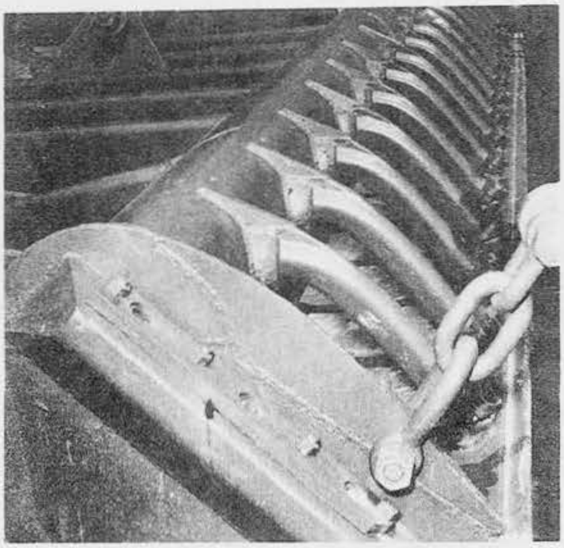

Fig. 28
Prototype installation for
dredge BURGESS

indicated would perform with equal efficiency. In the short time that these modifications have been in use, it is not possible to reach definite conclusions as to their ultimate value. However, performance of the dredge OCKERSON has indicated that end jets of the new design have been of decided advantage, particularly when operating in crossings which contain considerable amounts of silt and drift.

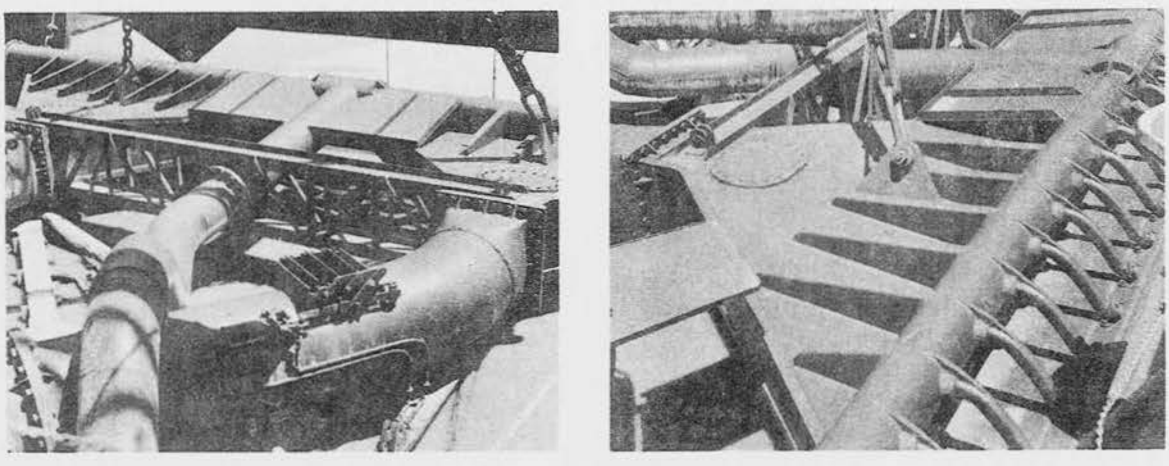

Fig. 29. Additional views of prototype installations

SUMMARY OF TEST DATA

Test No.	Description of Head					Pressures		Average Discharge cfs	Area of Cross Section Sq Ft	Rate of Advance Ft/Min	Rate of Cutting Cu Yd/Hr	Ratio
	Type	Location of Baffles	No. Regular Jets	Type End Jets	Floor Design	Jet Pressure psi	Suction Vacuum in. hg					
14A	Original Double	None	34	None	Flat	7.8	19.0	147	415	4	3690	3.72 to 1
15A	Original Double	None	34	Orig.	Flat	7.8	21.0	143	360	4	3190	3.72 to 1
16A	Original Double	None	34	None	Flat	5.2	21.1	142	390	4	3460	3.72 to 1
17A	Original Double	None	34	None	Flat	2.6	19.0	144	357	4	3170	3.72 to 1
18A	Original Double	None	34	Orig.	Flat	5.2	23.0	142	403	4	3580	3.72 to 1
19A	Original Double	None	34	None	Flat	5.2	20.0	141	403	4	3580	3.72 to 1
21A	Single	Dustpan	23	None	Flat	5.2	18.5	141	373	4	3320	5.08 to 1
23A	Single	Dustpan	12	None	Flat	5.2	18.5	141	309	4	2750	5.08 to 1
25A	Single	Dustpan	23	None	Flat	2.6	18.5	142	363	4	3230	5.08 to 1
26A	Single	Dustpan	23	None	Flat	7.8	18.5	144	395	4	3510	5.08 to 1
30A	Single	Revised Dustpan	23	None	Flat	5.2	19.0	137	375	4	3330	5.08 to 1
33A	Single	Revised Dustpan	23	None	Flat	7.8	19.5	130	385	4	3420	5.08 to 1
36A	Single	Revised Dustpan	23	None	Flat	5.2	20.0	127	383	4	3400	5.08 to 1
38A	Single	Revised Dustpan	23	None	Flat	7.8	20.0	133	390	4	3470	5.08 to 1
40A	Original Double	None	34	None	Flat	5.2	19.0	129	395	4	3510	3.72 to 1
41A	Single	Dustpan	23	None	Flat	5.2	19.0	134	383	4	3400	5.08 to 1
42A	Single	None	23	None	Flat	5.2	20.0	131	349	4	3100	5.08 to 1
47A	Single	Dustpan	23	None	Flat	5.2	20.4	121	401	4	3560	3.72 to 1
48A	Single	Dustpan	23	None	Flat	5.2	20.7	131	403	4	3580	3.72 to 1
49A	Single	Dustpan	23	None	Flat	5.2	19.8	130	394	4	3500	3.72 to 1
50A	Original Double	None	34	None	Flat	5.2	17.3	129	385	4	3420	3.72 to 1
52A	Original Double	None	34	None	Flat	5.2	19.4	135	390	4	3470	3.72 to 1
53A	Original Double	None	34	None	Flat	5.2	21.1	135	401	4	3560	3.72 to 1
6B	Original Double	None	34	None	Flat	10	21.0	153	408	4	3630	3.72 to 1
9B	Original Double	None	34	None	Flat	15	19.4	144	413	4	3670	3.72 to 1
10B	Original Double	None	34	None	Flat	20	19.1	146	418	4	3720	3.72 to 1
22B	Original Double	None	34	None	Flat	15	22.6	148	372	6	4960	3.72 to 1
23B	Original Double	None	34	None	Flat	15	21.5	146	406	5	4510	3.72 to 1
24B	Original Double	None	34	None	Flat	15	23.7	148	374	7	5820	3.72 to 1
25B	Remodeled Double	None	34	None	Flat	10	17.3	149	400	4	3560	5.08 to 1
26B	Remodeled Double	None	34	None	Flat	15	18.6	145	417	4	3710	5.08 to 1
27B	Remodeled Double	None	34	None	Flat	20	19.0	150	417	4	3710	5.08 to 1
28B	Remodeled Double	None	34	None	Flat	15	19.6	149	400	5	4440	5.08 to 1
29B	Remodeled Double	None	34	None	Flat	15	22.6	147	390	6	5200	5.08 to 1
30B	Remodeled Double	None	34	None	Flat	15	24.0	145	368	7	5730	5.08 to 1
31B	Remodeled Double	None	34	None	Raised	10	18.5	147	405	4	3600	4.04 to 1
32B	Remodeled Double	None	34	None	Raised	15	19.0	146	421	4	3740	4.04 to 1
33B	Remodeled Double	None	34	None	Raised	20	19.0	148	423	4	3760	4.04 to 1
34B	Remodeled Double	None	34	None	Raised	15	19.5	150	398	5	4420	4.04 to 1
35B	Remodeled Double	None	34	None	Flat	10	18.7	151	409	4	3640	4.04 to 1
36B	Remodeled Double	None	34	None	Flat	15	18.8	148	416	4	3700	4.04 to 1
38B	Remodeled Double	None	34	None	Flat	15	21.1	144	401	5	4460	4.04 to 1
39B	Remodeled Double	None	34	None	Flat	15	23.3	141	372	7	5790	4.04 to 1
40B	Remodeled Double	None	34	None	Flat	15	22.1	149	393	6	5240	4.04 to 1
41B	Remodeled Double	None	34	Orig.	Flat	15	18.9	148	429	4	3810	4.04 to 1

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SUMMARY OF TEST DATA (Continued)

Test No.	Description of Head					Pressures		Average Discharge cfs	Area of Cross Section Sq Ft	Rate of Advance Ft/Min	Rate of Cutting Cu Yd/Hr	Ratio
	Type	Location of Baffles	No. Regular Jets	Type End Jets	Floor Design	Jet Pressure psi	Suction Vacuum in. hg.					
42B	Remodeled Double	None	34	Orig.	Flat	15	18.8	150	444	4	3950	4.04 to 1
43B	St.-Line Double	None	34	None	Raised	15	18.4	148	421	4	3740	4.04 to 1
44B	St.-Line Double	None	34	None	Raised	20	18.9	149	425	4	3780	4.04 to 1
45B	St.-Line Double	None	34	None	Raised	10	18.8	149	414	4	3680	4.04 to 1
46B	St.-Line Double	None	34	None	Raised	15	20.2	147	402	5	4470	4.04 to 1
47B	St.-Line Double	None	34	None	Raised	15	21.8	150	393	6	5240	4.04 to 1
48B	St.-Line Double	None	34	None	Raised	15	23.6	149	376	7	5850	4.04 to 1
49B	Remodeled Double	None	34	None	Flat	15	18.0	151	416	4	3700	3.03 to 1
50B	Remodeled Double	None	34	None	Flat	20	17.6	146	420	4	3730	3.03 to 1
51B	Remodeled Double	None	34	None	Flat	10	18.1	154	406	4	3610	3.03 to 1
52B	Remodeled Double	None	34	None	Flat	15	19.7	146	407	5	4520	3.03 to 1
53B	Remodeled Double	None	34	None	Flat	15	21.6	145	394	6	5250	3.03 to 1
54B	Remodeled Double	None	34	None	Flat	15	22.8	144	374	7	5820	3.03 to 1
55B	St.-Line Double	None	34	None	Raised	10	18.7	147	420	4	3730	3.72 to 1
56B	St.-Line Double	None	34	None	Raised	15	18.7	152	422	4	3750	3.72 to 1
57B	St.-Line Double	None	34	None	Raised	20	18.9	147	421	4	3740	3.72 to 1
58B	St.-Line Double	None	34	None	Raised	15	20.5	147	410	5	4560	3.72 to 1
59B	St.-Line Double	None	34	None	Raised	15	22.4	146	390	6	5200	3.72 to 1
60B	St.-Line Double	None	34	None	Raised	15	23.8	147	374	7	5820	3.72 to 1
61B	Remodeled Double	27-in. pipes	34	None	Flat	10	21.4	145	408	4	3630	3.03 to 1
62B	Remodeled Double	27-in. pipes	34	None	Flat	15	28.8	144	358	7	5570	3.03 to 1
63B	Remodeled Double	27-in. pipes	34	None	Flat	15	24.7	146	387	5	4300	3.03 to 1
64B	St.-Line Double	None	17	None	Raised	15	19.9	152	408	4	3630	3.72 to 1
65B	St.-Line Double	None	17	None	Raised	20	19.9	149	408	4	3630	3.72 to 1
66B	St.-Line Double	None	17	New	Raised	15	20.2	152	437	4	3880	3.72 to 1
67B	St.-Line Double	None	17	New	Raised	20	20.3	148	447	4	3970	3.72 to 1
68B	St.-Line Double	None	34	New	Raised	15	19.9	149	447	4	3970	3.72 to 1
69B	St.-Line Double	None	34	New	Raised	15	21.7	147	442	5	4910	3.72 to 1
70B	St.-Line Double	None	34	New	Raised	15	23.6	150	425	6	5660	3.72 to 1
71B	St.-Line Double	None	34	New	Raised	15	24.0	143	382	7	5940	3.72 to 1
72B	St.-Line Double	None	34	New	Raised	20	19.4	152	446	4	3970	3.72 to 1
73B	St.-Line Double	None	12	None	Raised	15	18.6	150	390	4	3470	3.72 to 1
74B	St.-Line Double	None	12	None	Raised	20	19.0	151	401	4	3560	3.72 to 1
75B	St.-Line Double	None	12	None	Raised	15	20.1	144	350	5	3890	3.72 to 1
77B	Remodeled Double	Y-Branch	34	None	Flat	15	19.6	154	421	4	3740	3.03 to 1
78B	Remodeled Double	Y-Branch	34	None	Flat	20	20.2	147	415	4	3690	3.03 to 1
79B	Remodeled Double	Y-Branch	34	None	Flat	15	22.2	147	402	5	4470	3.03 to 1
80B	Remodeled Double	Y-Branch	34	None	Flat	15	25.1	144	387	6	5160	3.03 to 1
81B	Remodeled Double	27-in. pipes & Y-Branch	34	None	Flat	15	28.7	142	366	7	5700	3.03 to 1
82B	Remodeled Double	27-in. pipes & Y-Branch	34	None	Flat	10	20.3	150	404	4	3590	3.03 to 1
83B	Remodeled Double	Y-Branch	34	None	Flat	15	18.6	144	415	4	3690	3.03 to 1
84B	Remodeled Double	Y-Branch	34	None	Flat	15	20.2	147	403	5	4480	3.03 to 1
86B	Remodeled Double	None	34	None	Flat	15	20.9	147	402	5	4470	3.03 to 1
91B	Alt.St.-Line Double	None	34	None	Raised	15	22.1	150	393	5	4370	3.72 to 1
92B	Alt.St.-Line Double	None	34	New	Raised	15	22.7	148	424	5	4710	3.72 to 1
93B	Alt.St.-Line Double	None	34	New	Raised	15	19.7	150	438	4	3890	3.72 to 1
94B	Alt.St.-Line Double	None	34	None	Raised	15	22.4	147	392	5	4360	3.72 to 1
95B	Alt.St.-Line Double	None	34	None	Raised	15	20.0	150	409	4	3640	3.72 to 1
100B	St.-Line Single	Dustpan	24	None	Raised	15	19.6	152	399	4	3550	4.04 to 1

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SUMMARY OF TEST DATA (Concluded)

Test No.	Description of Head					Pressures		Average Discharge cfs	Area of Cross Section Sq Ft	Rate of Advance Ft/Min	Rate of Cutting Cu Yd/Hr	Ratio
	Type	Location of Baffles	No. Regular Jets	Type End Jets	Floor Design	Jet Pressure psi	Suction Vacuum in. hg.					
*101B	St.-Line Single	Dustpan	24	None	Raised	15	——	——	——	5	——	4.04 to 1
102B	St.-Line Single	Dustpan	24	New	Raised	15	21.1	——	396	5	4400	4.04 to 1
103B	St.-Line Single	Dustpan	24	New	Raised	15	19.0	147	406	4	3610	4.04 to 1
104B	St.-Line Single	Dustpan	24	None	Raised	20	21.0	——	369	5	4100	4.04 to 1
105B	St.-Line Single	Dustpan	24	None	Raised	20	19.1	147	405	4	3600	4.04 to 1
107B	Alt.St.-Line Double	Dustpans	34	None	Flat	10	19.9	150	385	4	3420	3.72 to 1
108B	Alt.St.-Line Double	Dustpans	34	None	Flat	15	21.4	144	376	5	4180	3.72 to 1
109B	Alt.St.-Line Double	Dustpans	34	None	Flat	15	19.8	142	398	4	3540	3.72 to 1
110B	Alt.St.-Line Double	Dustpans	34	None	Flat	20	18.5	146	400	4	3560	3.72 to 1
111B	Alt.St.-Line Double	Dustpans	34	None	Flat	20	21.0	147	400	4	3560	3.72 to 1
112B	Alt.St.-Line Double	Dustpans	34	None	Flat	15	23.5	142	353	6	4710	3.72 to 1

* Outside passages at head blocked after two minutes operation.