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CAPABILITY OF EXISTING 6-INCH BULK FUEL DELIVERY SYSTEMS TO TRA--ETC(U)
AUG 80 J BAYLES, N CLARKE, C HOFFMAN
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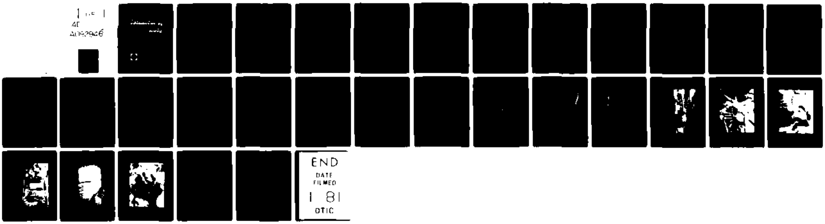

Technical Note

CEL

TN no. N-1585

title: CAPABILITY OF EXISTING 6-INCH BULK FUEL DELIVERY SYSTEMS TO TRANSFER FUEL FROM TANKERS 10,000-FT OFFSHCRE

author: J. Bayles, N. Clarke, C. Hoffman, and J. Thayer

date: August 1980

sponsor: Naval Facilities Engineering Command

program nos: Y0242-01-006

CIVIL ENGINEERING LABORATORY

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	TN-1585
2. GOVT ACCESSION NO.	DN687076 (AD-A092946)
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle)	CAPABILITY OF EXISTING 6-INCH BULK FUEL DELIVERY SYSTEMS TO TRANSFER FUEL FROM TANKERS 10,000-FT OFFSHORE
5. TYPE OF REPORT & PERIOD COVERED	Final – FY-76
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)	J. Bayles N. Clarke C. Hoffman J. Thayer
8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	CIVIL ENGINEERING LABORATORY Naval Construction Battalion Center Port Hueneme, California 93043
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	Y0242-01-006
11. CONTROLLING OFFICE NAME AND ADDRESS	Naval Facilities Engineering Command Alexandria, Virginia 22332
12. REPORT DATE	Augu[redacted]80
13. NUMBER OF PAGES	27
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	
15. SECURITY CLASS. (of this report)	Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

POL, Amphibious, Assault, Fuels, Buoyant hose, Pipeline, Flowrate, Fuel transfer, Fuel delivery, Booster pump, Towing, Causeway, Pipe tong

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents results of demonstration exercises in which two concepts utilizing existing equipment and vessels were tested to determine the capability of the Amphibious Construction Battalions to transfer fuel onshore from transports positioned 10,000 ft offshore in an amphibious assault. Data given includes pumped seawater delivery rates and projected comparative fuel flow rates.

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TN-1585   27 pp illus   August 1980   Unclassified

1. Fuel systems   2. Offshore delivery   I. Y0242-01-006

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CONTENTS

INTRODUCTION

The Civil Engineering Laboratory (CEL) was tasked, as part of an investigation of the Navy/Marine Corps Amphibious and Advanced Base POL Systems, to determine the capability of the Navy's Amphibious Forces to meet the projected onshore fuel needs of a Marine Amphibious Force (MAF) using existing 6-in. bulk fuel delivery systems. This document reports results of April 1976 demonstrations based upon scenarios developed to test this fuel delivery capability, referred to in the text as the "NOW" capability.

BACKGROUND

The Amphibious Construction Battalions (PHIBCB's) have the responsibility for deploying ship-to-shore fuel delivery systems up to 5,000 ft in length to support assault operations. Equipment allowances of each PHIBCB include assets to deploy two systems each of 5,000 ft of buoyant hose and 5,000 ft of bottom-laid pipe; these four lines are 6 in. in diameter. In addition, PHIBCB ONE has a portable third hose system that has a powered hose reel with interchangeable 1,000-ft-capacity hose drums. None of the systems have an integral fuel pumping capability; the delivering fuel transport ship must pump the fuel ashore.

Revised Operational Requirement

In January 1976, a revised Operational Requirement (Ref 1) defined new requirements for fuel delivery and tanker moorings. These new parameters include fuel delivery up to 10,000 ft offshore at flow rates great enough to meet MAF fuel consumption and build fuel storage reserves. In a MAF operation, fuel consumption between D+0 and D+15 steadily increases, reaching a maximum of about 1 mgd. Analysis of consumption levels and storage requirements indicates that a tanker-to-shore fuel system for a MAF operation should be able to deliver up to 2 mgd. The OR also states that the system must operate in sea state 5 conditions and survive sea state 6, with 4-kt currents and 75-kt winds.

Development of Possible Concepts

These performance thresholds cannot be met by the existing offshore fuel system. Development and testing of new interim concepts that use existing equipment and personnel allowances to increase fuel delivery capability became imperative. These new concepts could be used should a MAF operation become necessary during the time it takes to study the overall POL amphibious assault fuel system and complete the development program necessary to fully meet the performance stated in the OR.

Several 10,000-ft-long fuel line concepts using assets existing in 1976 were developed by CEL. Three of these were selected as the most promising for interim use. Additionally, a modified version of each of the three concepts (in which a booster pump in the line was added) was also considered. Two of the concepts and their modified versions were demonstrated by PHIBCB ONE off Silver Strand Beach at Coronado, Calif., during April 1976.

DEMONSTRATION

The objectives of the April 1976 demonstration were:

(1) To determine the degree of capability of the Naval Amphibious Forces to meet the new OR for offshore fuel delivery during MAF-sized assault operations while using only assets currently held

(2) To determine the benefits derived from providing a booster pump station in the line at sea (at the seaward 5,000-ft point for the demonstration).

This work did not include delivery ship moorings. The capability of present moorings for larger delivery tankers in required environments is known (Ref 2) to be inadequate, necessitating the reduction of times on station to mild conditions only; the acceptable conditions for any particular ship can be determined analytically.

Approach

CEL recognized that there was no integral fuel pumping capability in the then-current Table of Allowances (TOA) of equipment held by the PHIBCB's. Preliminary studies, however, indicated that a booster pump would be required in the line if the projected fuel flow rate requirement were to be approached. Therefore, when it was determined that an integral pumping capability could be incorporated with very little design change in the conceptual systems, modified versions of the concepts being developed were considered. Figures 1 through 3 illustrate the three concepts considered most viable and promising, including the addition of booster pump stations.

The three concepts and the modified versions were discussed with personnel of PHIBCB ONE and refined in accordance with their recommendations. It was then determined that PHIBCB ONE would conduct demonstration exercises using as many of the concepts as time would permit. PHIBCB ONE subsequently elected not to undertake the "all bottom-laid" version (Figure 3) because of the uncertainty of being able to retrieve the 10,000-ft pipeline without damage. PHIBCB ONE planned the demonstration exercises and obtained the required assets.

The two necessary fuel pumps were obtained from the Marine Corps First Force Service Support Group, Camp Pendleton, Calif., from Amphibious Assault Fuel System assets. The pumps were Federal stock item FSM 4930-110-5777, rated to pump 600 gpm at 125 psig discharge pressure.

CEL agreed to provide observers at each point of activity during the demonstrations, obtain data on flow rate and pipe retrieval forces, and prepare a report on the demonstrations.

During detailed discussion of the concepts with PHIBCB ONE prior to the demonstration, it was determined that none of the three systems or their modified versions would significantly alter the current PHIBCB mission, TOA, or method of implantation out to the seaward 5,000-ft point. From that point on, however, significant changes were anticipated. Table 1 itemizes data on the booster pump installation in the line at a point about 5,000 ft offshore. Table 2 provides a basis for consideration in the event the all-bottom-laid concept is tested at a future date.

Descriptions of Concepts

Figures 1 through 3 illustrate the concepts developed. For the demonstration, one of the Marine Corps fuel pumps mounted on a causeway section located at the seaward terminus of the flow line simulated a fuel tanker. For the concepts presented in this report, pumps on a typical fuel tanker would give approximately the same performance as the Marine Corps pump used in this demonstration.

A second Marine Corps pump mounted on a causeway section was moored astride the fuel line path 5,000 ft offshore. This pump was connected so that the pump could be used as a booster or it could be bypassed to demonstrate the performance of a system without a booster pump.

For the version depicted in Figure 3, both pumps would be located at the seaward terminus of the fuel line. If this version were tested, one pump was to simulate the tanker, and the other was to boost the line pressure to about 250 psig. This second pump, which would be an integral component of the line system, could be mounted on a causeway section or the tanker's deck. The 250-psig discharge pressure of the second pump would require a new discharge hose to run from the pump to the pipeline. The steel pipe can operate at the higher pressure.

Demonstration Exercises

A base camp with all required assets (Figure 4) was established at the beach site. The site was prepared in the manner customary for assembly of the bottom-laid pipe system. The approximately 33-ft-long pipe sections were made up into strings of five pipe sections each. The towing bridle and riser hose assembly was married to the first pipe string and made ready for towing. A warping tug passed its A-wire ashore, and this wire was joined to the towing bridle. The warping tug pulled the pipeline seaward as each string was added (Figure 5). The tug used only its propulsion units to provide towing forces. A flagman and radio operator ashore directed the tug crew when to start pulling after each pipestring addition or to cease pulling as the shoreward pipe end reached the pipe tong. The A-wire was slacked off to stop the pipe movement since tug momentum was not easily arrested. When 2,500 ft of pipe had been deployed, a second tug was joined abreast of the first tug, and its A-wire was also attached to the towing bridle. From this point, the two tug crews operated in concert. Following placement of the pipeline and buoying off the towing bridle/riser hose, the intermediate causeway section booster pump station was moored seaward of the end of the pipeline. The buoyed-off towing bridle/riser hose was retrieved, brought aboard, and secured. A pump discharge pigtail hose assembly (Figure 6) was joined to the riser hose.

Aboard the intermediate causeway, a pump inlet pigtail hose assembly secured to the deck was joined to an assembly of nine lengths of buoyant hose and associated stress wire made up in the customary manner. This assembly was faked on deck. Following completion of installation of the booster pump station, one tug took the seaward pump platform causeway section under tow abeam. In addition to serving as the seaward pump platform, this causeway served as the mounting platform for the portable powered hose reel and buoyant hose drums (Figures 7 and 8). This tow approached the booster pump station, and the seaward end of the buoyant hose assembly faked on deck aboard the booster station was taken aboard. As the preassembled buoyant hose was towed to sea, its seaward end was joined to the hose mounted in the portable powered reel. Emplacement of the buoyant hose (4,000 ft) proceeded in the customary manner until the seaward 10,000-ft (nominal) point was reached (see Table 3 for lengths). The causeway section was then moored, and the hose was connected to the seaward pump (simulated tanker). The combination system depicted in Figure 1 was then ready for testing. To test the system without the booster pump, the booster pump was bypassed by connecting the inlet and outlet hose pigtails at that location.

Meanwhile, during establishment of the bottom-laid pipe assembly site, other personnel faked out a preassembled buoyant hose/stress wire on the beach. The length of this assembly was sufficient to reach the booster pump station. For this demonstration, the hose assembly had been placed on the beach as an expedient alternative to mounting the hose on a hose reel for deployment. A warping tug deployed this hose by passing its A-wire to the beach and then towing the hose and attached stress wire to the booster pump station.

Upon completion of testing of the combination bottom-laid pipe/buoyant hose system (Figure 1), the riser hose pigtail connection at the pump was replaced by coupling the end of the shoreward nominal 5,000 ft of buoyant hose directly to the pump to form the buoyant system shown in Figure 2. For testing without the booster pump, the adjacent ends of the two 5,000-ft (nominal) hose assemblies were coupled together directly.

To determine the flow rates attained during testing, a calibrated 6-in. Hersey-Sparling Torrent Model "T" meter (Figure 9) was installed at the shore discharge end of each system. Two 50-ft lengths of 6-in. buoyant hose were added at the meter discharge to direct the discharged water back to the sea. Flow rates are shown in Table 3. Table 4 translates these seawater flow rates into equivalent fuel flow rates.

The systems were retrieved in the customary manner. An initial attempt to retrieve the pipe without first expelling the water with air to reduce the negative buoyancy was unsuccessful because the forces required were beyond the capability of the D8K tractor winch. The bottom-laid pipe had been in place approximately 72 hr. The forces required for pipe retrieval were determined by installing a load cell in the towing line and collecting the data by means of a strip chart recorder. Forces required to retrieve only the first three 90-ft sections of pipeline were measured. This was done to determine the greatest resistance encountered to achieve breakout. Figure 10 shows the rate of reduction of required force for succeeding pulls for each of the three 90-ft pipeline sections. Immediately following indication of breakout, the winch was stopped momentarily then restarted.

Problems Encountered

1. The pipe used in these demonstrations was contaminated with rust, dirt, and debris. While filters are used in the onshore POL system, it is generally considered good practice to contribute as little contamination to the fuel as possible during each step of the delivery process. The condition of the pipe probably results from its unprotected outside storage between operations. Also, a considerable amount of sand entered the pipe during handling and assembly on the beach.

2. During pipeline retrieval, when the final lengths of bottom-laid pipe were drawn up on the beach, four of the last six pipe lengths were found to be bent. One of them was bent so much that it would not pass through the pipe tongs and had to be cut out of the line by torch. This damage was attributed to tug and pipeline misalignment at times during towing to sea.

3. During pipeline installation the effects of towing forces could not be observed from the sea surface. Divers had to remove (and then reinstall) the towing bridle/riser hose assembly from the pipeline in order to undo a number of 360 deg twists found to have developed during pipeline towing. These twists prevented fluid flow when pumping was first attempted.

4. When the towing bridle/riser hose assembly attached to the pipe was drawn up on the beach following pipeline retrieval, it was discovered to have been badly damaged - with a number of hose carcass penetrations. It is possible that water leakage through these penetrations affected flow rate data.

5. The design configuration of the pipe tong set (Figure 5) requires that the pipe be positioned in precise alignment within the tong set, both as it enters and leaves. If sufficiently out of alignment, pipe couplings will hang up on the tong jaws, possibly damaging the tong set.

6. During retrieval of the bottom-laid pipe, the pipe tongs were sensitive to the amount of sand carried into them on the pipe. Blowing the sand off with compressed air and sweeping by broom reduced the problem.

7. During pipeline retrieval, the pipe tongs did not develop sufficient torque to break the pipe connections easily; heavy rapping of the pipe couplings with a sledge hammer assisted.

8. The shoreward 5,000-ft buoyant hose system which had been deployed from the beach (Figure 2) remained unused for a significant period of time (overnight) while the combination system was tested. During this time, sea action caused many full twists to occur in the hose and stress wire, particularly in the surf zone and on the beach. These twists prevented fluid flow until manually corrected by shore parties and small boat crews.

9. During its idle period, the shoreward buoyant hose filled with water and sank below the surface, which prevented examination by personnel in surface craft prior to pumping operations.

10. Hose had been too loosely installed on the seven hose drums of the portable powered hose reel resulting in unnecessary difficulty in deploying the hose through the reel (see Figures 7 and 8).

11. Several pieces of equipment (such as the towing bridle/buoyant hose assembly and pipe retrieval adapter), are very difficult to handle by personnel, because of their weight and size.

12. As is so often experienced, communication among the several distant, simultaneous, and dependent operations proved to be a major difficulty during these demonstrations. Only one radio frequency was available, and the alternate telephone system proved inadequate, generally being unusable.

13. Booster pump station barge installation at the midpoint of the fuel line, proved to be so difficult an operation in what was estimated to be a sea state 3 condition that installation attempts were abandoned until the seas calmed somewhat. The use of independent mooring legs with buoys would expedite barge installation and would reduce the chances for fouling mooring hardware on the pipeline or riser hose. These legs (four each per barge) could be placed after pipeline installation, using the location of the pipeline to locate the legs. The standard NAVFAC Oil Barge Mooring (Ref 3) would be in the standard or perhaps a lightened version; such legs can be assembled from a combination of present PHIBCB and other Fleet hardware.

In addition, a number of small problems were encountered which could be attributed to the demonstration being the first of its kind and the consequent unfamiliarity of operating personnel with the procedures as a whole. However, items 1 through 12 are problems not caused by the increase in length of the fuel lines but are characteristic of 5,000-ft installations as well.

Although no significant reliability problems were encountered with the pumps, the possibility of such problems makes it desirable that a bypass be used on an operational booster station. The bypass provides a degraded flow rate alternative, rather than a complete shutdown, in the event of a booster pump problem.

COMPARISON OF NOW CAPABILITY AND REQUIRED CAPABILITY

Summarized below are the major operational requirements related to fuel transfer, followed by a brief description of the NOW capability as concluded from the results of this demonstration.

<u>Fuel Line Length</u>

OR - The fuel line must extend up to 10,000 ft offshore.

NOW - The fuel line can extend to 10,000 ft offshore with either two buoyant systems in series or a combination of a bottom-laid and a buoyant system in series.

Flow Rates

OR - The concept must meet maximum MAF consumption (1 mgd) while building fuel storage levels.

NOW - The concepts tested can supply about 900,000 gpd (operating 20 hr/day at an average flow rate of 750 gpm) each, when using an intermediate booster pump. This flow rate will approach MAF consumption but provides no reserve for building storage. Also, at 900,000 gpd a Military Sealift Command (MSC)-sized tanker would have to remain on-station more than 12 days to unload its cargo, a very severe demand.

Environmental and Operational Suitability

OR - Installation in sea state 3 conditions is mandatory. Operation in sea state 5 and survival in sea state 6 with 4-kt currents and 75-kt winds are necessary. Ability to survive a hurricane with 24-hr notice and return to operation within 48 hr when recalled are also needed. Installable/operable with present assets.

NOW - The intermediate booster pump and buoyant hose would be extremely difficult to install in sea state 3 conditions, but the bottom-laid pipe installation should be possible. During the demonstration, sea conditions never approached sea state 5, so operational and survival thresholds are not known. However, there is little possibility that the buoyant hose system or booster pump station will operate or survive in severe sea conditions. Furthermore, additional manpower and equipment are needed to install and operate booster pump stations. Therefore, the NOW capability falls far short of the OR in this category.

CONCLUSIONS

1. The combination concept, in which the bottom-laid pipeline is installed out to 5,000-ft and the buoyant hose system completes the full line out to 10,000 ft, would best support the MAF amphibious operations if the need arises during the period it takes to develop a system that fully meets the OR.

2. The PHIBCB's did not possess adequate TOA assets to meet the revised OR demands on the ship-to-shore fuel delivery capability.

3. The current PHIBCB TOA does not provide sufficient assets to support two beaches simultaneously with 10,000-ft ship-to-shore fuel delivery systems.

4. Assuming environmental conditions permit operation, two, parallel, 10,000-ft systems using the concepts demonstrated could provide flow rates which would exceed maximum consumption rates given in the OR. Parallel configurations would also allow transfer of two types of fuel simultaneously.

5. Adding a booster pump midway in a NOW-capability fuel line is feasible and will increase flow rates by about 50%. However, the booster pump increases system installation time, adds new manpower and equipment requirements for operation and maintenance, and increases the system's sensitivity to environmental conditions.

RECOMMENDATIONS

1. The combination system of bottom-laid pipe and buoyant hose rather than a continuous buoyant hose, is recommended for use should a NOW-capability system be required. Benefits of this selection include: the buoyant hose will not be in the sea surface area near the beach obstructing lateral surface craft traffic nor be subjected to the severe conditions of the surf zone. Also, using one buoyant hose system and one bottom-laid system gives each PHIBCB the capability to install two identical 10,000-ft fuel lines. For a MAF-sized operation two parallel systems, both with booster pumps, are recommended. Such a configuration will supply adequate flow rates when it is operating. Because of the systems' sensitivity to environmental conditions, however, a high degree of reliability cannot be expected.

2. When a booster pump station is installed, it should incorporate a valved bypass so that the pump can be cut out of the line without interrupting flow from the tanker.

3. Independent mooring legs with buoys should be utilized to moor the booster pump station against moderate-to-heavy seas. This would prevent the possibility of dropping mooring anchors on the pipeline or riser hose when mooring the station.

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1. Chief of Naval Operations. Operational Requirement OR-YAW13: Offshore mooring/fuel transfer and storage. Washington, D.C., Jun 1977.

2. Civil Engineering Laboratory. Technical Memorandum no. 55-79-03: "A comparison of tanker mooring and fuel transfer concepts for the offshore bulk fuel system (OBFS)," by D. A. Davis. Port Hueneme, Calif., Feb 1980.

3. *Naval Facilities Engineering Command.* Design Manual DM-26: Harbor and coastal facilities; chapter 7: mooring design physical and empirical data; section 14: mooring for degausing and oil barges. Washington, D.C., Jul 1968.

Table 1. Data Relevant to Installation and Operation of Booster Pump Stations for Combination or Buoyant-Hose System Concepts

Item	Source		Estimated Confidence in Availability	Comments
	For Demonstration	For Mobilization		
Pump	USMC - 600-gpm fuel pump from Camp Pendleton, Bulk Fuel Co.	USMC - 600-gpm fuel pump	Doubtful	--
		500-gpm fire pump North Island, NAS	Doubtful	Doubtful application
		Investigate Army sources	Doubtful	--
Pump Station Platform[a]	PHIBCB ONE	Same as for demonstration	Good (exists)	Causeway section (3 x 5 intermediate) may require addition to TOA; can be built to needs; modificaton of moorings required
		ACU/NBG[b]	Good (exists)	MIKE 6 or MIKE 8 modifications required
Moorings[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	May require additional fleet moorings; mod-ify for deeper depth

(continued)

Table 1. Continued

Item	Source		Estimated Confidence in Availability	Comments
	For Demonstration	For Mobilization		
Hose/Pump/Pipe Adapters[a]	PHIBCB ONE	PHIBCB ONE	Good (exists)	--
Communications Equipments[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	PRC 25; sound powered phone
Personnel[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	Two men full-time for 10-hr shift
Platform Shelter for Personnel Comfort and Support Items[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	Tent, hooch, equipment shelter
Pump Station Fuel Storage[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	Drums, tank, truck, pontoon module tank
Pump Station Engine Fuel Transfer[c]	PHIBCB ONE	PHIBCB ONE	Good (exists)	Hand pump
Pump Station Engine Refueling Support	PHIBCB ONE	NBG/PHIBCB	Good	Tank truck, MIKE boat, etc.; coordination problem possible
Pump Station/ Fuel Line Marker Lights	PHIBCB ONE/NBG	NBG	Good (exists)	Possible coordination problem

(continued)

Table 1. Continued

Item	Source		Estimated Confidence in Availability	Comments
	For Demonstration	For Mobilization		
Maintenance and Operating Personnel Transport Support	ACU/NBG/PHIBCB ONE	NBG/PHIBCB ONE	Good (exists)	Warping tug, Lark, MIKE boat; possible coordination problem

[a]Warping tug A-wire to be used to make and break hose connections at the pump station.

[b]ACV - Assault Craft Unit; NBG - Naval Beach Group.

[c]Items are in TOA; however, existing inventory may not be up to allowance.

Table 2. Data Relevant to Installation and Operation of High Pressure Booster Pump Station for an All-Bottom-Laid Pipeline System Concept

Item	Source		Estimated Confidence in Availability	Comments
	For Demonstration	For Mobilization		
Pump	--	--	Doubtful	Requires high pressure pump
Pump Station Platform	PHIBCB ONE	PHIBCB ONE	Good (exists)	Full size pontoon barge
Moorings	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1
Discharge Hose Adapters for Hose, Pump, and Pipe		a	Good	Not in TOA
Communications Equipment	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1
Personnel	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1
Platform Shelter: Personnel Comfort and Support Items	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1
Pump Station Fuel Storage	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1

(continued)

Table 2. Continued

Item	Source		Estimated Confidence in Availability	Comments
	For Demonstration	For Mobilization		
Pump Station Engine Fuel Transfer	PHIBCB ONE	PHIBCB ONE	Good (exists)	Same as Table 1
Pump Station Engine Refueling Support[b]	PHIBCB ONE	NBG/ACU/ PHIBCB ONE	Good	Same as Table 1
Pump Station/ Fuel Line Marker Lights	PHIBCB ONE/NBG	NBG	Good (exists)	Same as Table 1
Maintenance and Operating Personnel Transport Support[b]	ACU/NBG/ PHIBCB ONE	NBG/PHIBCB ONE	Good (exists)	Same as Table 1

[a]Emplacement is beyond the capability of assets now in TOA and may well require modification of mission statements of other military units to require their support of the PHIBCB's. Examples may be:

(a) To provide a means (or craft) such as ATF; buoy tender; cable layer; YTM or salvage ship to tow the pipeline to sea.
(b) To provide high pressure pumps and hose for connecting pumps to pipelines.

[b]With the booster pump station at 10,000 ft rather than 5,000 ft, these items assume greater significance with respect to availability of transport craft and their utilization time for this purpose.

Table 3. Fluid[a] Delivery Rates for Systems Tested

Concept	Pump Discharge Pressure (psig)		Flow Rate (gpm)[c]	System Discharge Pressure (psig)
	Seaward Pump[b]	Booster Pump		
Combination				
5,300 ft of pipe; 4,000 ft of hose				
Booster pump connected	95	125	715-745	10-11
Booster pump bypassed	105-120	N.A.	570-610	7-8
Buoyant hose only				
9,922 ft of hose; booster pump located 5,922 ft from shore				
Booster pump connected	90-95	120-130	770-790	12-16
Booster pump bypassed	125	N.A.	550-590	8-10

[a]Seawater used as fluid in tests.

[b]Portable pump station identical to booster station used seaward to simulate ship's pump.

[c]750 gpm for 20 hr/day yields 900,000 gal/day.

Table 4. Equivalent Fuel Flowrates for the Systems Tested

[Calculated from Table 3 for fuel versus seawater]

Concept	Booster Status	Flowrate[a] (gpm)		
		Seawater	Diesel	JP-5
Combination	operating	745	714	784
	bypassed	610	522	607
Buoyant hose	operating	790	734	841
	bypassed	590	528	640

[a]Flowrates were calculated assuming typical diesel and JP-5 fuels at an ambient temperature of 60°F, pumped under conditions identical to those during the test.

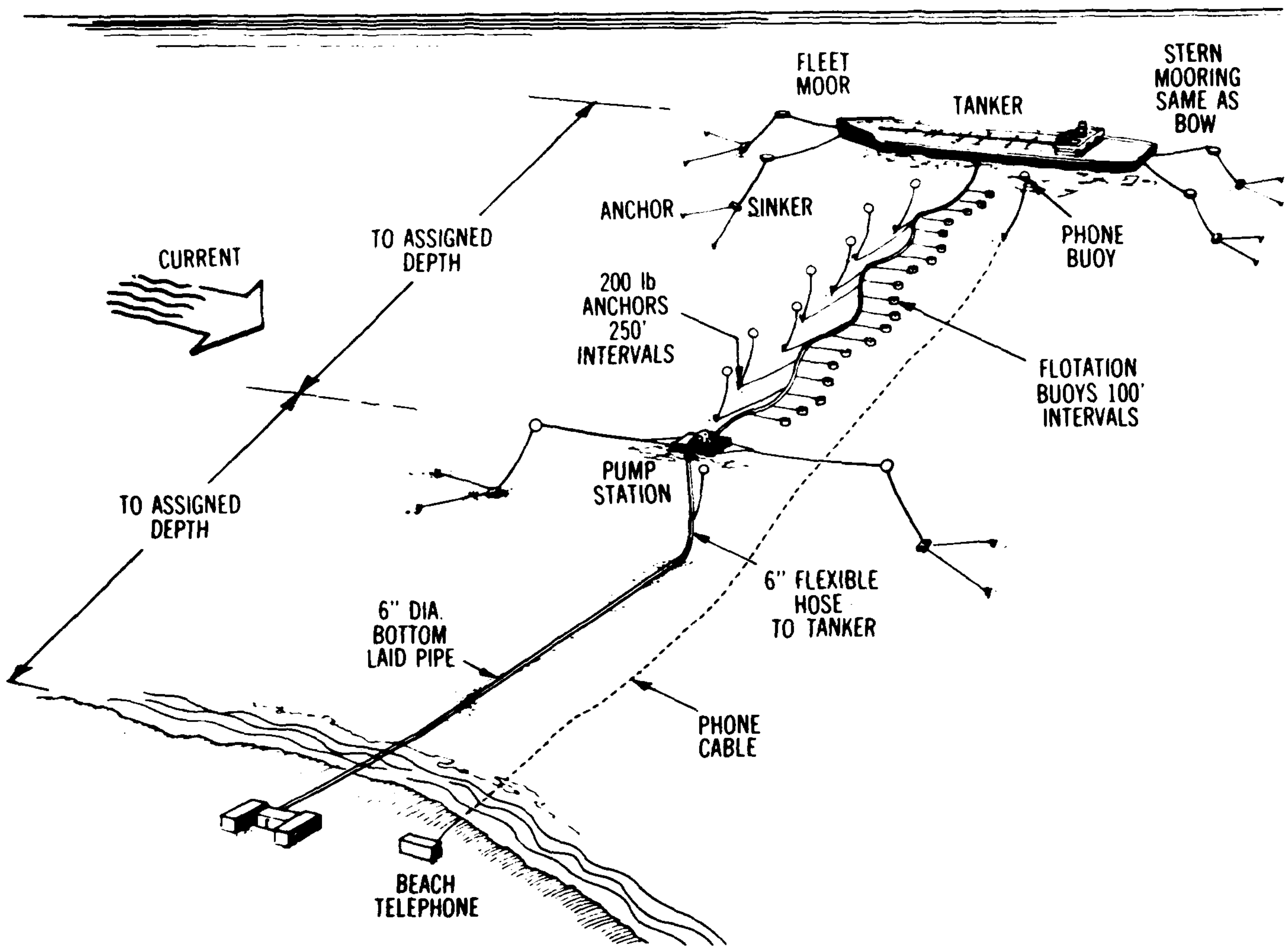

Figure 1. Combination extended amphibious assault bulk fuel system (AABFS).

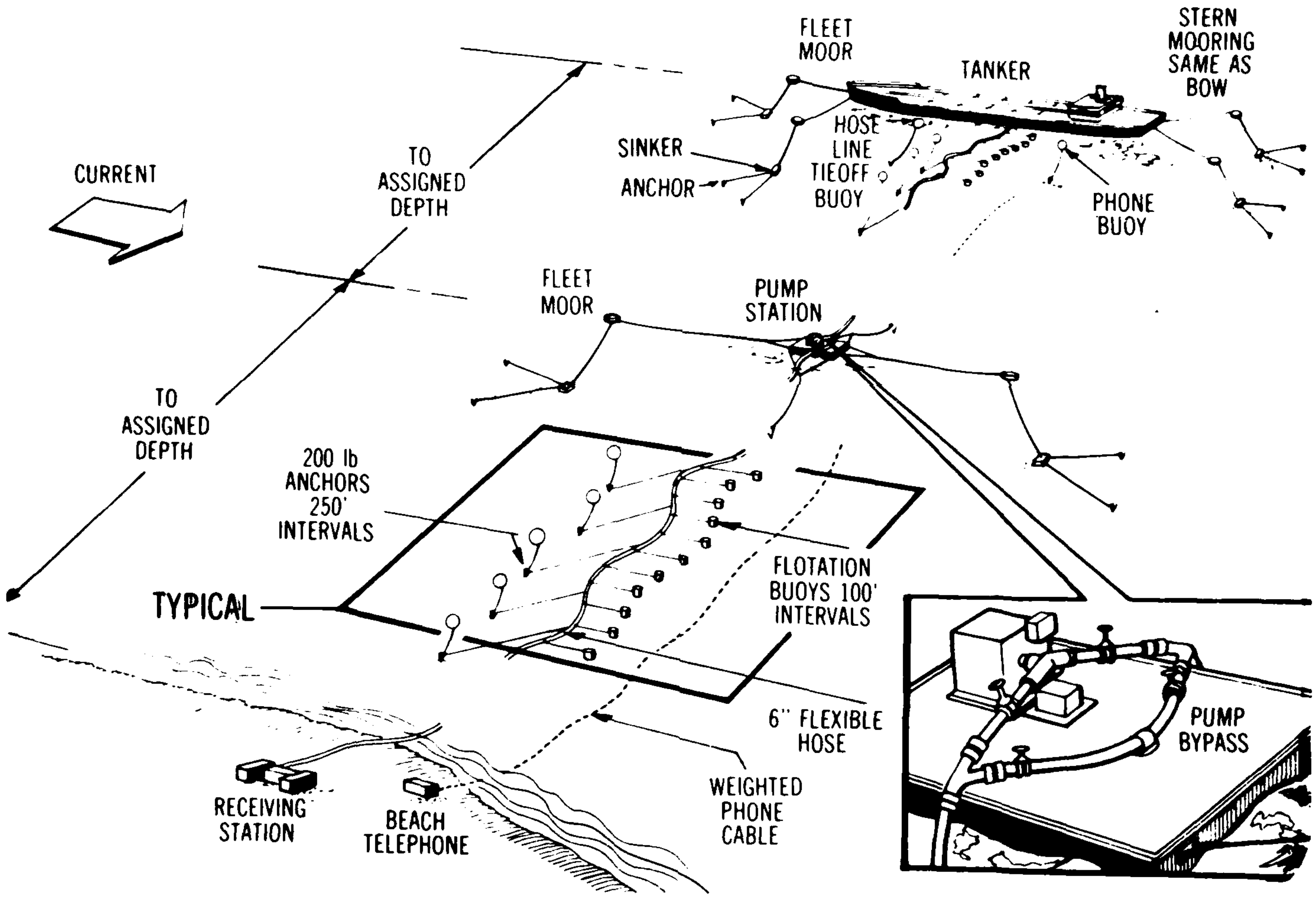

Figure 2. Buoyant extended amphibious assault bulk fuel system (AABFS).

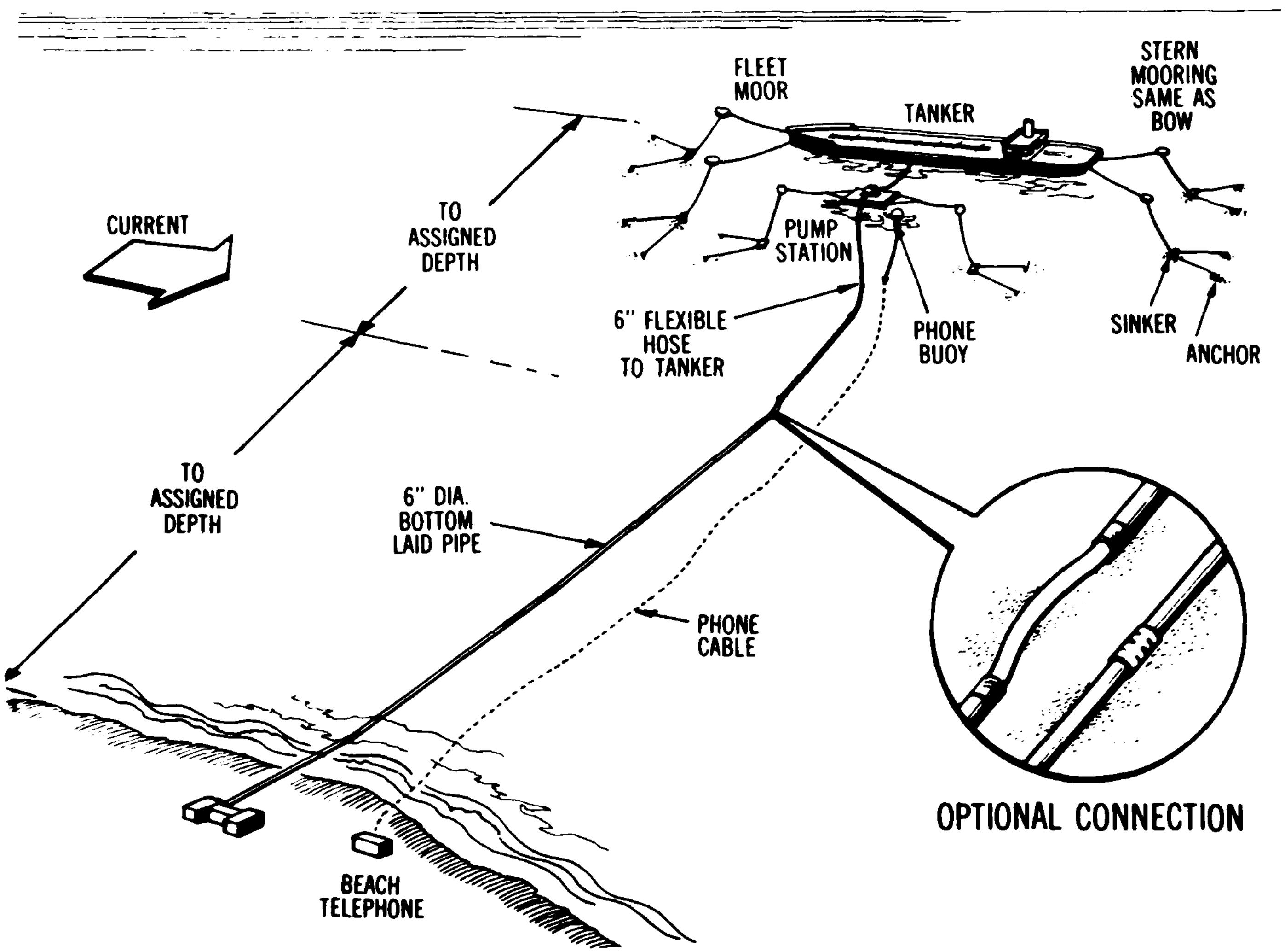

Figure 3. Bottom-laid extended amphibious assault bulk fuel system (AABFS).

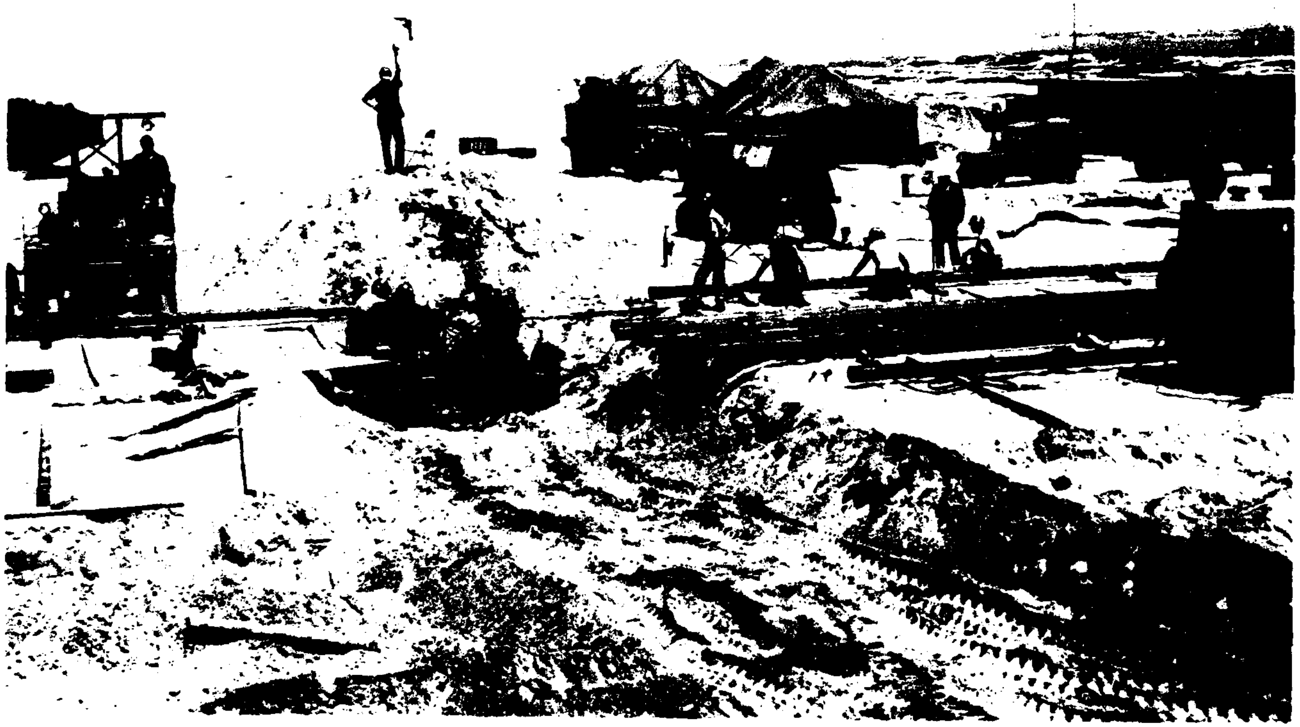

Figure 4. PHIBCB beach assembly area for bottom-laid AABFS for offshore fuel line.

Figure 5. PHIBCB pipe tong crew.

Figure 6. Booster pump station.

Figure 7. Portable powered hose reel.

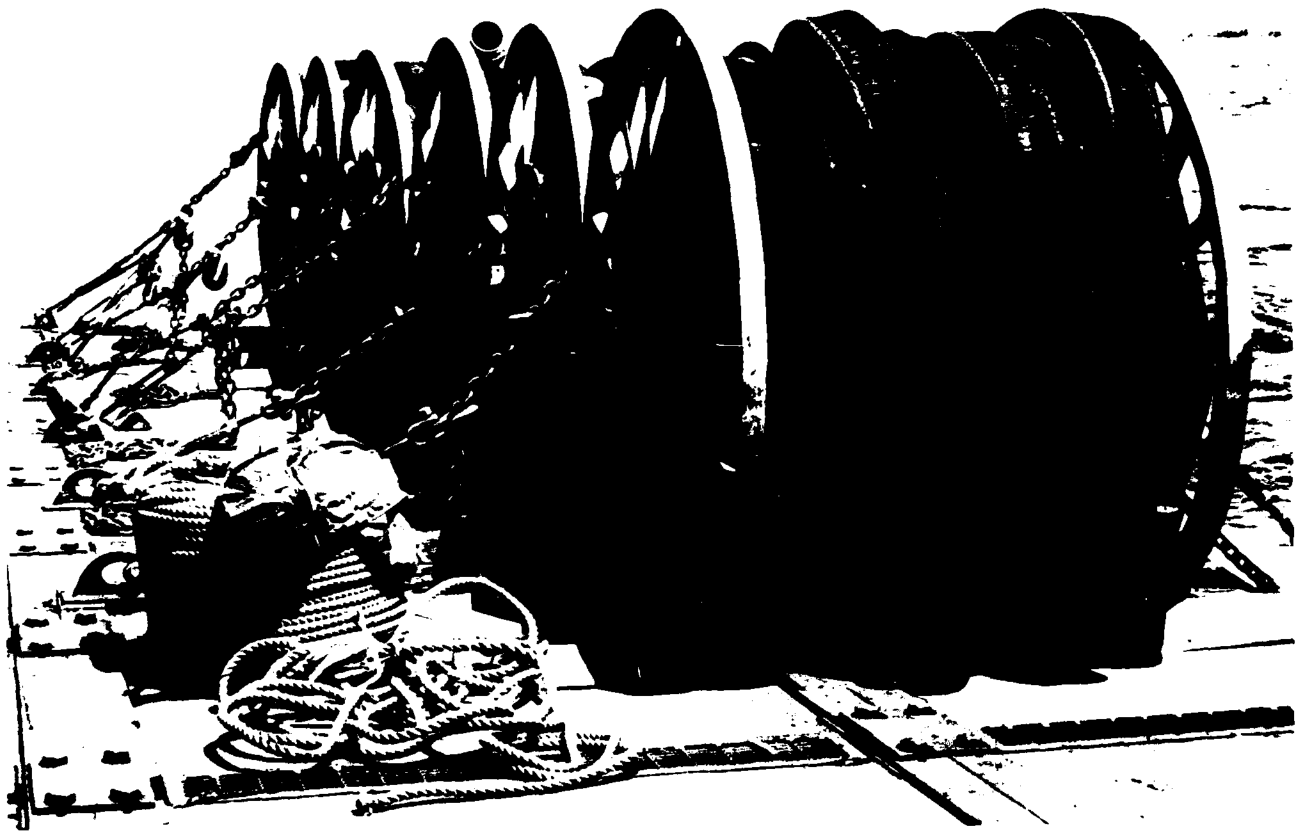

Figure 8. Drums of buoyant AABFS 6-inch hose.

Figure 9. Six-inch Hersey-Spading flowmeter.

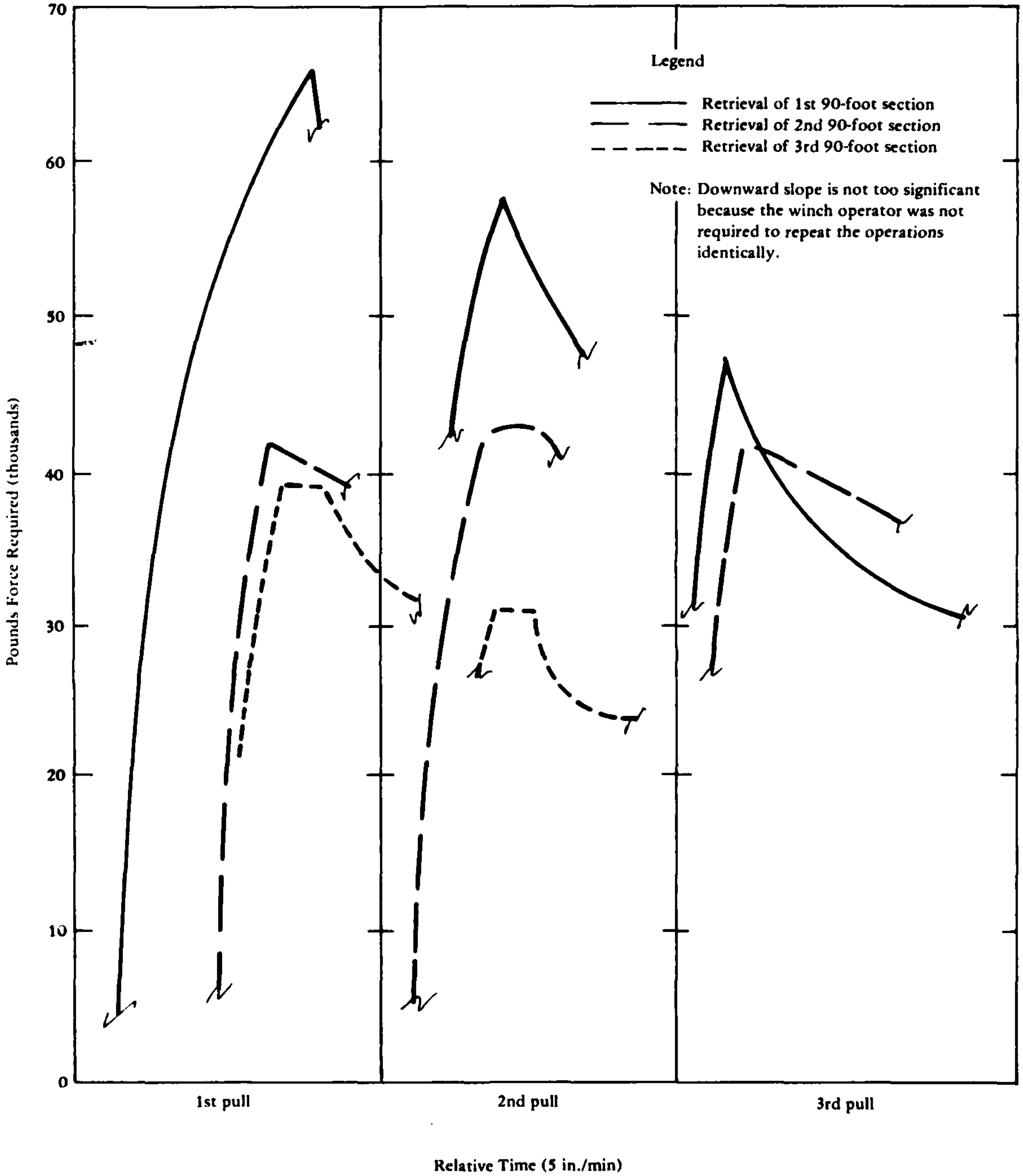

Figure 10. Excerpts from bottom-laid pipeline retrieval force data. (Peak is when breakout reduces tension, winch was then stopped momentarily then started again for the next pull.)

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