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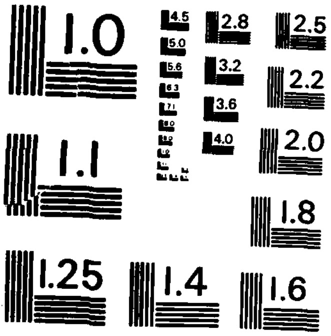

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SUBSEA CABLE BURIAL SYSTEM

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SUBSEA CABLE BURIAL SYSTEM

OUTLINE OF CONCEPTUAL DESIGN

MALCOLM MELLOR

USACRREL

for

NAVAL FACILITIES ENGINEERING COMMAND

December 1976

Contents

SUBSEA CABLE BURIAL SYSTEM

CONCEPTUAL DESIGN

Problem definition

At the inception of this project, the problem was defined in the NAVFAC Statement of Work, and performance requirements were subsequently reviewed as the first stage of the work. However, more recent discussions, especially those held at the Naval Civil Engineering Laboratory in Port Hueneme, have changed our perception of the problem. In particular, it seems that extreme roughness of the bottom topography may be an unavoidable operating condition, and there may be a significant number of sites where a "soft rock" machine will be incapable of penetrating the bed material.

The effect on our thinking has been to focus more attention on the carrier vehicle for the burial unit, and also to consider the desirability of interchangeable burial units for soft rock and hard rock.

Personnel at NAVFAC have also been influenced by recent discussions, and a revised concept guide was issued to CRREL in December. This document is included here as attachment #1.

Outline of System and Functions

Goal. The goal is to bury undersea cable in various kinds of bed material, including hard bottom. It is desirable to have a self-contained machine that can operate across beaches, through the surf zone, and along the sea bed to the 150 ft water depth.

Operating Options. There are three broad possibilities for laying and burying cable:

(a) Lay cable first, bury later;

(b) Lay and bury simultaneously;

(c) Trench or bore the bed material first, lay or thread cable later.

This machine is required to bury a number of cables that are already laid, so that option (a) is required unless the cables are to be taken up and relaid. However, as far as the design and operation of the machine is concerned, there need not be much difference between options (a) and (b).

Functions and subsystems. The burying machine has to provide for a number of distinct but interrelated functions, which govern the design of machine subsystems. The main functions are as follows:

(1) Penetration of the bed material.

(2) Material removal from the trench, tunnel or borehole.

(3) Wall support in the trench, tunnel or borehole.

(4) Laying in the cable

(5) Carriage of the burying unit

(6) Propulsion of the carrier vehicle and burying unit

(7) Power supply

(8) Power transmission

(9) Final drives

(10) Control, guidance and monitoring

For each individual function, a number of concepts are available. However, the chosen concepts for each of the functions have to be mutually compatible when combined into the total system.

Design Constraints

The system is intended to be operated by Underwater Construction Teams of Navy Construction Battalions. Preparation, operation and maintenance should not be unduly complicated.

The equipment has to be deployed at widely scattered sites in various parts of the world, and there is a requirement for it to be transportable by C-141 aircraft. It must also be transportable by road. If the equipment has to be broken into separate modules for transport, then preparation and reassembly must be simple procedures that do not call for special equipment or heavy lifting gear.

The performance required from this system is significantly beyond the present state-of-the-art, but there is no provision for R&D. While the complete system will be innovative, it must employ existing component parts and developed technology.

Although the proposed cable burying operations are not governed by ordinary economic factors, there are limits to the costs of acquisition and operation.

Penetration of the Bed Material

There are a number of concepts available for penetrating the bed, and most of them have been discussed already in the state-of-the-art assessment. They can be summarized as follows:

A. Mechanical cutting. This covers the use of backhoes, plows, rippers, disc saws, wheel ditchers, chain saws, ladder trenchers, milling drums, cutterhead dredges, roadheading machines, impact breakers, percussive drills, vibratory plows, rotary drills, tunnel boring machines, and so on.

B. Fluid jets. For practical purposes this group of concepts is confined to use of water jets, either with or without entrained solid particles. It covers continuous jets, pulsed or modulated jets, discontinuous slugs, cavitating jets, and jets of sand/water mixtures.

C. Explosive techniques. This covers conventional drill and blast operations, use of conventional shaped charges, use of flexible linear shaped charge, gas blasting, special blasting techniques, and innovative application of liquid and slurry explosives.

D. Exotic methods. This is a catchall category for concepts that are applicable in principle, but not very promising for the present job. It covers thermal, electromagnetic and chemical concepts, and the more unlikely mechanical concepts, such as free projectile impact.

Material Removal.

Material has to be removed from the furrow, trench, borehole or tunnel to accommodate progress of the penetrating unit and to permit entry of the cable. The techniques available can be summarized as follows:

A. Direct mechanical transport. This covers devices such as screws, scrolls, auger flights, conveyor belts, bucket chains, displacement blades, scrapers, and so on.

B. Fluid transport. This covers movement of solid material as a fluidized solid, a slurry, or a suspension, using either air or water as the carrier fluid. It can involve jetting, pumping, or sucking, either in an open system or in a closed circulation system.

C. Direct lateral displacement. This is applicable to porous materials, compressible materials, and easily deformable materials. Material from the trench, furrow, or borehole is pushed laterally to allow the penetrating unit to progress.

D. Exotic methods. This is another catchall category to cover methods that are not likely to be applicable for this job. An example is material removal by phase change (solution, melting, vaporization).

Wall support

The walls of the trench, tunnel or borehole have to stay apart long enough for the penetrating unit to pass ~~and pass~~ and for the cable to be laid in. The following possibilities can be envisaged:

A. Competent material - no support needed.

B. Fixed mechanical restraint. This could involve cross-braced sheeting, sheet piling, borehole casing, steel or concrete tunnel lining, pressure bags, fluid pressure, and such like.

C. Traveling supports. Temporary mechanical support could be provided by things like moveable sheeting, tunneling shields, slip forms, or feed shoes traveling immediately behind the penetrating unit.

D. Ground treatment. This covers grouting, cementation, freezing, and so on.

Laying in the cable

The main possibilities for laying-in procedure are the following:

A. Payout from a fixed site on the bed or the shore. Cable could be laid into open trench directly by bottom pull, or it could be passed through a feed shoe while fresh cable is drawn to the machine by bottom pull.

B. Payout from a surface vessel or submersible. Cable can be led from storage reels on a support vessel to the feed shoe of the burial unit, or into open trench.

C. Payout from the cable burying machine. Cable can be laid into the trench or tunnel from a storage reel on the trenching or boring unit.

D. Pickup of previously laid cable. The burying machine can track along the line of a previously laid cable, picking it up and feeding into the bed behind the penetration unit.

Carrier vehicle for the burying equipment.

Some kind of carriage is needed for the burying equipment. Possibilities include:

A. Sled
B. Tracked vehicle
C. Wheeled vehicle
D. Walking machine
E. Bouyant submersible craft
F. Surface vessel
G. Hybrid device

The carrier has to support the burying equipment as it traverses from the beach, through the surf zone, and over a variety of bottom conditions. Bed material ranges from very soft sand and mud to hard rocks. Topography ranges from perfectly flat bottom to extremely rugged rocky terrain. The equipment has to withstand waves and currents. Forces developed by the burying operation itself will probably be transmitted to the carrier.

Propulsion of the carrier vehicle and burying unit

When the burying equipment is actually working, it can be propelled in various ways:

A. Self-propelled from bed reaction or sidewall reaction. This could be by wheels, tracks or pads on the sea bed, on the sides of the trench or bore, or on the pipe or cable that has to be buried. Rolling chains can be included in this group. Self-propelling cutter units can also be included.

B. Self-propelled from fluid reaction. This might involve jets, propellers, thrusters, and such like.

C. Surface tow. This includes towing of the sea bed unit by a continuously moving surface vessel or by an anchored vessel, using either a tow cable or a rigid towbar (stinger).

D. Bottom pull. This includes direct kedging using anchor points and winches, and also pulling from the beach via direction-changing sheaves. It can also include arrangements where the carrier moves intermittently and moves the penetrating unit relative to itself.

E. Direct thrust. This could be applied in rotary drilling.

Power supply

There are two broad possibilities for location of the power source:

A. Integral power supply. This could be a primary diesel source with a snorkel, a set of electric storage batteries, fuel cells, or some more exotic arrangement.

B. External power supply. With external power supplied from the beach or from a surface vessel, the primary source would almost certainly be diesel, although there are other possibilities.

Power transmission

The first concern here is with power transmission from an external power source to the sea bed unit. Excluding exotic and inappropriate concepts, the possibilities are:

A. Mechanical transmission. This covers machines like conventional cutterhead dredges, ladder dredgers, rotary drills, surface-towed plows and rippers.

B. Hydraulic transmission. Direct hydraulic transmission involves a pump at the surface power source and hydraulic motors on the sea bed unit. The umbilical has hydraulic hoses.

C. Electric transmission. This involves an electric power source on the surface and electric motors on the sea bed unit. The umbilical has an electrical cable.

D. Pneumatic transmission. This requires a compressor at the surface and air motors on the bed unit. The umbilical carries air hoses.

Final Drives

The final drive outputs to tracks, winches, cutters and so on are likely to be mechanical. The incoming power from an outside source has to be transmitted through the sea bed unit, and if necessary converted to the required mechanical output. Possible systems for converting and transmitting the incoming power are:

A. Mechanical. This is applicable where power is supplied mechanically. It may involve gears, drive chains, belts, shafts, rollers, clutches, and so forth.

B. Hydraulic. With an input of hydraulic power, final drives can be turned by hydraulic motors, either directly or via mechanical components.

C. Electrical. With an input of electrical power, final drives can be turned by electric motors, either directly or via mechanical components. The electric motors can be of a type designed for direct submersion, or they can run in a sealed compartment, driving a power takeoff through a rotating seal.

D. Pneumatic. With an input of compressed air, final drives can be turned by air motors.

E. Hybrid. The most obvious hybrid system is electro-hydraulic. Incoming electrical power drives a high voltage motor, which drives a hydraulic pump, which in turn supplies hydraulic motors. The electric motor and the hydraulic pump can be run in a sealed compartment, so that there is no need for waterproofing the motor or for rotating seals.

Control, Guidance and Monitoring

The operations of the carrier and the burying equipment have to be controlled, the equipment has to be steered along the desired path and made to avoid extreme obstacles, and continuous checks have to be made on the performance of the total system and the main subsystems. Possible arrangements include:

A. Complete local control. This depends on having an operator on or along side the equipment all the time it is working, either a diver or a man in a chamber.

B. Complete remote control. This calls for remote control of all major subsystems, sensing and telemetering of machine operations, and remote interpretation of sensor signals.

C. Combination of local control and remote control. This can take a variety of forms, but generally the goal will be to keep the overall subsystem as simple as possible.

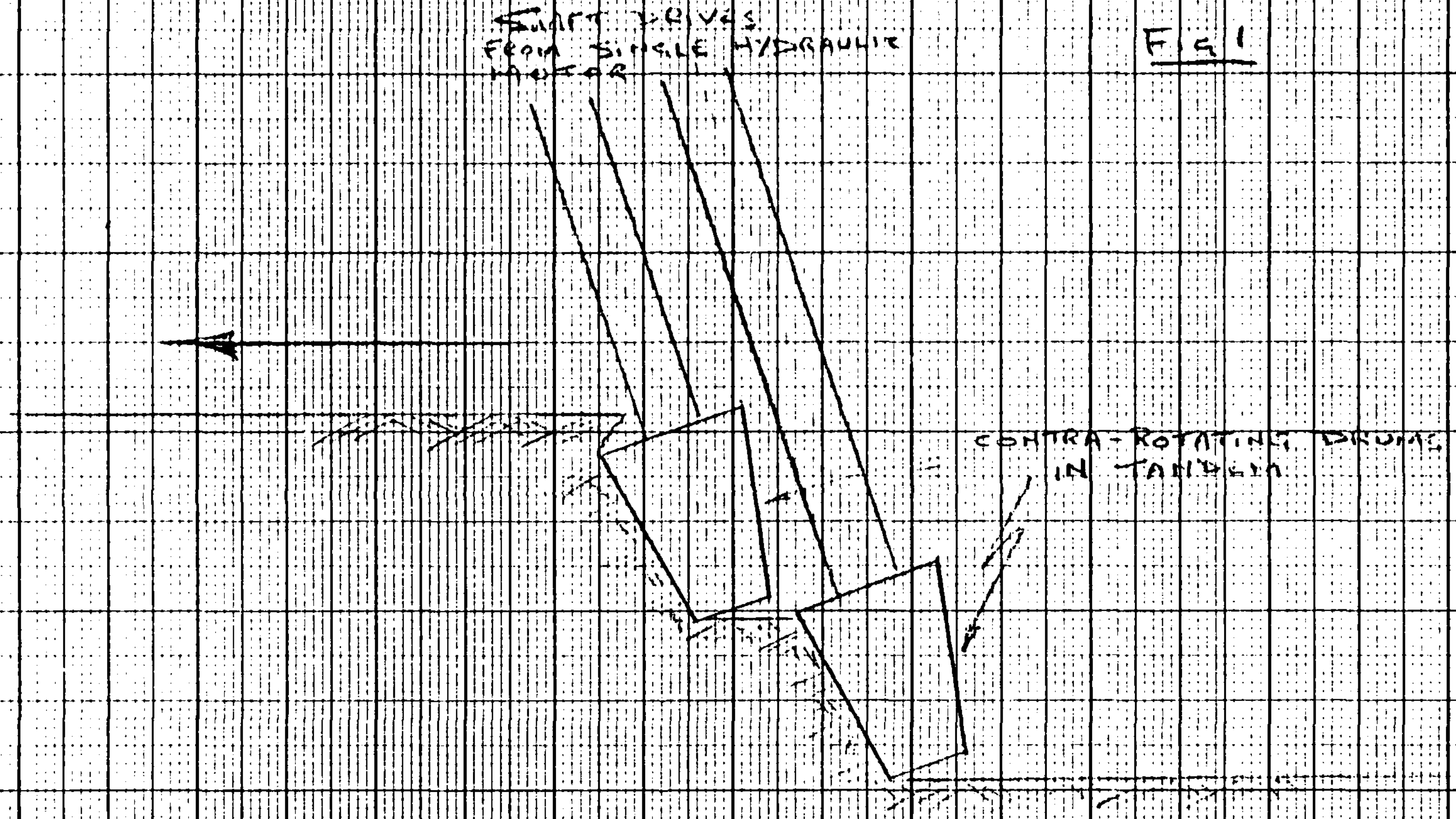
Selection of Subsystem Concepts

1. Penetration. We obviously have to rule out exotic concepts. Explosive methods have been ruled out explicitly by NAVFAC, although we believe that they are well worth considering for very hard rock. Fluid jets could probably be made to do the job, but power demands would undoubtedly be very high, and there would be high risk of operational problems. We feel that high pressure water jets for underwater rock trenching should receive some R&D attention, but until an experimental prototype has been demonstrated on land or under the sea, the concept cannot be safely applied to an operational system that is required to employ state-of-the-art technology. This leaves mechanical cutting.

For undersea pipe burial in tough soils, cutterhead machines seem to be the choice of most designers, and there is undoubtedly a possibility of upgrading performance still further by using cutterheads that are similar to those developed for mining and tunneling in rock. Cutterheads and milling drums are not well adapted for slicing narrow slots, but there is a possibility of getting down to trench widths of about 1 ft. The lateral force problem of slot milling could be overcome by having two contra-rotating heads traveling in tandem in different depth ranges, as shown in fig. 1.

For trenching in hard ground on land, special modifications are made to either wheel cutters or chain saws. Wheel ditchers are being developed for work in permafrost, but so far the performance has not been outstandingly successful. On a smaller scale, disc saws have been developed for slot cutting in frozen ground, concrete, and some rocks. Perhaps the most versatile kind of ditcher for work in ordinary

Fig 1


SHAFT DRIVES FROM SINGLE HYDRAULIC MOTOR
CONTRA-ROTATING DRUMS IN TANDEM

soils is the ladder trencher, and this type of machine has been developed for work in harder materials. However, more robust chain saws such as those used in the mining industry provide a more suitable starting point for hard ground trencher development.

Making a choice between the wheel and chain configurations, we tend to favor the chain. Some of the reasons are as follows:

1. For deep digging, wheels are large and cumbersome.
2. Changes in digging depth alter the cutting geometry of a wheel and change the direction of the resultant axle force very significantly.
3. Cutting teeth on an upmilling wheel enter the work with almost zero depth of bite, which tends to enhance wear rates.
4. A chain saw can vary the digging depth and the direction of the resultant force independently.
5. Depth of bite for a cutting tooth on a chain remains more or less constant throughout the working sweep.
6. A chain has some self-cleaning tendency because of extreme flexure at the end sprockets.

About the only advantage of a wheel is the fact that it needs only one bearing, whereas a chain has many bearings and sliding surfaces.

The choice of a chain saw for this task is quite clear cut. It has the capability of working in both soft bottom and in some of the weaker rocks, while making only modest demands in terms of power, traction and reaction. Like any other drag bit device, a chain saw will not operate economically in very hard rock (say over 20,000 lbf/in^2 compressive strength), and it may well show unacceptable wear rates in rocks of only moderate strength (say over 10,000 lbf/in^2).

In soft bottom, a chain saw may well be unnecessarily complicated. Our design will make provision for replacement of the saw with a simple plow if jobs have to be carried out at sites where there is no hard bottom.

In very hard bottom, where there are exposures of igneous rocks or hard metamorphics, the saw will not work. We have a concept for trenching hard rock with percussive chisel tools, but this is definitely not state-of-the-art - it calls for R&D effort to develop an experimental prototype. However, our design will make provision for replacing the saw with a percussive machine if one becomes available, and if the need arises.

2. <u>Material Removal</u>. Having selected a chain saw for penetration, the material removal function will be primarily mechanical with the cutting teeth sweeping the cutting up to the free surface. There should be little tendency for cuttings to spill back along the chain, as it is inducing a water flow in the required direction. If necessary, scraper blades can be set in among the cutters, but these are not likely to be needed. For work in sticky clay, a small cleaning jet might be needed near the upper sprocket.

3. <u>Wall support</u>. The obvious method of providing wall support is by means of a traveling shield. This can hold the walls apart and keep out settling debris until the cable has been laid in. The traveling shield in this case will be a feed shoe set directly behind the chain saw. The cable will slide in a smooth curve through a duct inside the feed shoe, emerging at the base of the trench cut by the saw.

4. Laying in the cable. The immediate requirement is for the equipment to work at sites where cable is already in position on the sea bed, so that the machine will track along the cable, picking it up and paying it into the trench through the feed shoe. For work at new sites, there are various procedures that can be followed. The only procedure that our design will not accommodate is payout of cable from the burying machine; such a procedure makes very little sense.

5. Carrier vehicles. The extravagant mobility requirements that have been discussed in connection with this project lead in the direction of a large complex machine that would in all probability be too expensive for the project budget, too big to meet the transportation constraints, and too complex to suit the operating personnel. Such a behemoth would be out of proportion to its required function.

We have made an arbitrary decision, and taken what in our judgement appears to be the best *state-of-the-art compromise*. We have conceived a vehicle that has high capabilities for negotiating very rough terrain, expedient capability in very soft ground, and the ability to carry required payloads. It is not an ideal carrier for a rock cutting unit, in terms of compliance, but it should be adequate.

The general idea is to have the carrier behave like a crocodile, walking over the hard ground and sliding on its belly in the muck. This can be achieved with a tracked vehicle that has a smooth sled-like belly. In order to negotiate obstacles and provide stability with limited vehicle width, an articulated configuration is envisaged.

Development of new vehicles is very expensive, and therefore we propose to assemble the new machine from modifications of well tried existing vehicles. The cost goal is to rely on basic hardware that sells for approximately $100K (plus engineering and assembly).

6. Propulsion. Having chosen a tracked carrier, the primary propulsion will be provided by track shear on the bed. This may be insufficient for maximum performance trenching in very soft material, when the carrier vehicle is behaving like a sled. For supplementary traction, kedging winches will be provided.

7. Power supply. For this application, we can probably reject integral power supply. The burying machine has fairly high power requirements (probably over 200 hp), so that electrical storage batteries of the size that could be carried in a comparatively small vehicle would need frequent recharging. An internal combustion engine would need a large snorkel, and a 150 ft high snorkel would be a real problem in rough seas. The most reasonable solution seems to be a primary diesel source on the beach or on a surface vessel.

8. Power Transmission. For power transmission from the external source to the sea bed unit, the only strong candidates are hydraulic and electrical systems. In broad terms, high voltage electrical transmission is efficient and practical over long distances, whereas hydraulic transmission involves heavy losses if long distances are involved. Until the question of the final drive system is settled and the question of tether length is finally resolved, we cannot make a proper choice between the electric and hydraulic alternatives. If a short umbilical is acceptable, (CEL engineers set 600 ft. as a practical limit) then hydraulic transmission may be preferable. Its advantages include diver safety, relative

simplicity (including simplification of final drive), and avoidance of heat dissipation problems on the sea bed unit. If a long umbilical is necessary (NAVFAC calls for 2500 ft), then it may be necessary to use high voltage electrical transmission. To transmit hydraulic power over long distances it is necessary to either accept heavy losses or use large diameter hoses. Large diameter hoses are expensive, bulky and difficult to manage (a 2500 ft umbilical will add significantly to the traction requirements of the carrier vehicle).

9. Final drives. The final drive system depends on the main power transmission system, which so far has not been chosen. However, the choice is between electrical and hydraulic input. If the incoming power is electric, then the final drive will be either electric or electro-hydraulic. If the incoming power is hydraulic, then the final drive will be hydraulic. Track drives can be handled conveniently with either electric or hydraulic motors, since not much power is needed. The cutter drive will consume most of the power - perhaps something of the order of 200 hp. The cutter chain will probably run at constant power or constant torque. It is very likely that hydraulic actuators will be used on the vehicle articulation joint and on cutter bar positioning controls, so that there will be a need for at least some hydraulic power.

On balance, a pure hydraulic system seems most attractive, with an electro-hydraulic system as an alternative. A purely electric system is probably not practical, although direct electric drive of the cutter is definitely possible.

10. Control, Guidance and Monitoring. Ideally, the burying equipment should have complete automatic remote control. However, complete remote control of all functions calls for a complex and expensive subsystem. The prototype of such a system will almost certainly create operation and maintenance problems for UCT's. Because there are so many uncertainties about more basic subsystems (cutter and vehicle), we feel that it would be unwise to rely immediately on complete remote control.

Complete local control is the easiest option for a designer, and it is certainly a good way of gaining experience with an entirely new kind of machine. However, when the system is operating smoothly it may be neither necessary nor desirable to have local control.

Taking into account logistic constraints, cost factors, and the pioneering nature of the project, we opt for a combination of local control and remote control. Local control would be used for startup and sumping in, for operation over very rough terrain, for maintenance, and for overcoming special problems. Remote control would be used for routine operations with easy bed conditions, and for operation in hazardous conditions.

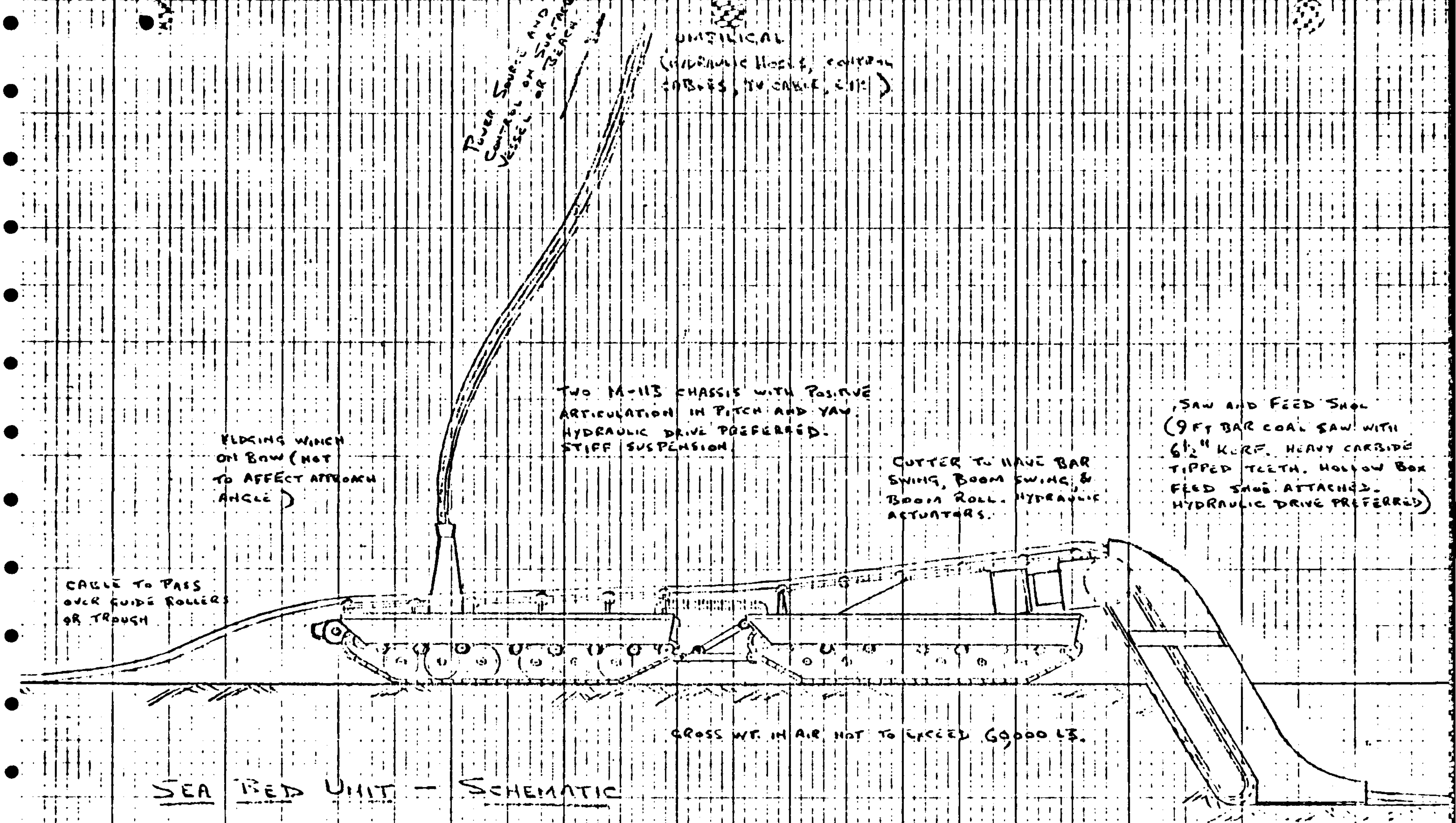
To simplify guidance, we favor heavy reliance on route survey, pre-setting of cable, and placement of suitable bed markers. Some simple expedients include: (a) properly laid cable (no spaghetti tangles), (b) optical targets (perhaps with high intensity strobe lights), (c) anchor points for kedging cables. We have reservations about the cable-follower devices that have been discussed, since it is desirable to have the cutter traveling along straight lines and smooth curves (not wedeling along the wiggles of the cables). In the first stage of development, manual remote steering seems preferable to automatic unless the operating conditions are specially favorable (tracking to a strobe beacon over smooth bed, kedging to a pre-set anchor point).

Cutting depth on the saw will not be continuously varied, but will be set at a selected value that can be changed from time to time as material properties change. This change can be made manually, by either local control or remote control. A decision to change depth can be made by direct inspection of the bed material when local control is being exercised. For remote control, the decision will probably be based on readings of feed rate and power consumption.

Feed rate (travel speed) ought to be adjusted continuously so as to draw full cutter power, or some predetermined percentage of full power that is governed by digging depth (keeping power density approximately constant). This adjustment can be made manually, or by means of a servo feedback from the cutter motor to the traction motors or winch motors.

Bar angle on the cutter will be pre-set and maintained at some selected value.

NAVFAC and CEL apparently expect a control to keep the trench vertical. This can be arranged by a self-plumbing control, but the effects are not quite as simple as they might seem. There is a possiblity that a plumbing control might be more bother than it is worth.



SEA BED UNIT – SCHEMATIC

APPROX. SCALE 0 2 4 6 8 10 FT

MM. 31 DEC. '76 (HAPPY NEW YEAR!)

ALTERNATIVE SCHEME WILL RETAIN MORE HULL STRUCTURE OF M-113

FIG. 2

Summary and Conclusions

We propose that the subsea cable burying machine should have a heavy duty rock-cutting chain saw followed by a closed feed shoe for laying in the cable. The equipment can be carried on a two-unit articulated crawler tractor that has positive control of pitch and yaw. The units will have smooth belly plates that can function as sleds in soft muck. The track system will be a military type for obstacle negotiation, but it will be stiffly sprung to carry a heavy load and to provide a stiff reaction to the pulsating cutter forces. Propulsion will be by tracks wherever possible, aided by kedging winches in difficult conditions. Power will be supplied from an external diesel source located either on the beach or on a surface vessel. Power transmission will be either electric or hydraulic, subject to further discussions with NAVFAC. Final drives will be hydraulic, electric, or electro-hydraulic. The control and guidance system will utilize both local control and remote control, and will be the simplest system that is capable of providing adequate performance. Emphasis will be given to route selection, pre-placement of cable, and pre-set guidance points.

The problem definition is still inadequate. We are uncomfortable about the lack of specific site information, and the lack of input from experienced UCT field personnel. We would draw special attention to the following points:

1. The requirements levied are beyond the present state-of-the-art.
2. Variable cutter width is not easy to provide.
3. Ideas of combining pipe-burying and cable-burying capabilities in the same machine are highly questionable unless pipe diameter is limited to a few inches.

4. The requirement for "sidehilling" performance will cause trouble (on steep sideslopes, any vehicle will sideslip slightly, causing the saw and feed shoe to bind).

5. A minimum umbilical length of 2500 ft limits the options on power transmission.

6. A 2500 ft umbilical dragged from the beach makes significant traction demands on the vehicle.

7. It is not clear to us how a burying machine could be operated and maintained a mile or more from the shore without a surface support vessel.

These matters will be discussed further in the next report.

Attachment #1

3 December 1976

CABLE TRENCHER

CONCEPT GUIDE FOR CRREL

SUB SYSTEMS

I. TRACK CONFIGURATION

Look at all configuration including:

(1) single pair of tracks
(2) two pair of tracks
(3) tricycle track
(4) any others

Constraints

1. C-141 payload limit - 70,000 lbs. (actually it's close to 100,000 lbs.)
2. C-141 width limit - 9'6". (should be 12½")
3. Limit of large crane on beach - 20,000 lbs.
4. Seabee's should not attempt assembly on beach which is technically complicated or requires availability and use of complex or sensitive equipment and tools.
5. Must transit over 2 feet high step obstacle.
6. Must transit over loose sand.
7. Must transit over open trench 5 feet across and 3 feet deep.

II. TRENCHER

Favored concept - Ladder.
Also consider others.

Constraints

1. Must cut trench 7' deep 12" wide in sand. Must cut trench 2 1/2' deep 6" wide in coral and soft stone.
2. Min. embedment speed .5 fpm.
3. Cutting teeth replaceable either individually or in groups (segments) as easily and quickly as possible (underwater).
4. Self sharpening cutting teeth are desireable.

III. POWER GENERATION AND TRANSMISSION

Consider all types including:

(1) Hydraulic
(2) Elect.-Hydr.
(3) Electrical

Constraints

1. Must provide support from either beach or surface platform.
2. Preferable to allow protection of diver from electrical cable break while on machine, operating it during short emergency periods and during return to beach.
3. Tether from beach - 2,500 feet long minimum.
4. Tether from surface platform - 600 feet long minimum.
5. Eventual system certification for diver safety must be considered as influencing any degree of high voltage electrical usage near diver, even for short periods.
6. Power cable must be capable of connection and disconnection by diver at trencher at depths of 135 feet.

IV. DRIVE SYSTEM

Consider: (1) Hydraulic
(2) Electrical

For hydraulic system, output of transmission must be divided into separate circuits of pumps and drive motors. Each hydraulic circuit will separately drive each track, trenching mechanism and the various controls.

Normal operation will be remotely controlled.

Constraints

1. Transit speed on level terrain - 100 fpm.
2. Maximum slope climbing capability - 45°.
3. Capable of diver operated local hydraulic control in emergency.

V. CONTROL SYSTEM

Normal operation will be remotely controlled. Automatic versus manual yet to be resolved. Cable will be laid along previously surveyed and cleared route prior to embedment, available for guidance of trencher. LLLTV with pan and tilt will be mounted on trencher for general overall viewing when water clarity permits. Compass will be mounted to TV camera within FOV (Field-of-view).

Constraints

1. Must provide support from either beach or surface platform.
2. Preferable to allow protection of diver from electrical cable break while on machine, operating it during short emergency periods and during return to beach.
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IV. DRIVE SYSTEM

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(1) Hydraulic
(2) Electrical

For hydraulic system, output of transmission must be divided into separate circuits of pumps and drive motors. Each hydraulic circuit will separately drive each track, trenching mechanism and the various controls.

Normal operation will be remotely controlled.

Constraints

1. Transit speed on level terrain - 100 fpm.
2. Maximum slope climbing capability - 45°.
3. Capable of diver operated local hydraulic control in emergency.

V. CONTROL SYSTEM

Normal operation will be remotely controlled. Automatic versus manual yet to be resolved. Cable will be laid along previously surveyed and cleared route prior to embedment, available for guidance of trencher. LLLTV with pan and tilt will be mounted on trencher for general overall viewing when water clarity permits. Compass will be mounted to TV camera within FOV (Field-of-view).

END

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