

A New Design Concept for Nodule Mining System

G. JANAKIRAMAN, R. VENKATESAN AND V.S.RAJARAMAN

National Institute of Oceanography, Dona Paula, Goa-403 004, India

ABSTRACT

An overview is presented on the hazards associated with various types of equipment to be used for the commercial mining of nodules from the seabed. The design of a suitable mining collector and the various options available are discussed. A novel idea of acoustically controlled free diving miner vehicle homing on to the riser and buffer combination which would improve commercial mining economy is put forward.

INTRODUCTION

Vast amounts of polymetallic nodule resources have been surveyed by various countries throughout the world. India had carried out extensive exploration and research in the Central Indian Basin (CIB) and has been awarded the exclusive mining rights for an area of 0.15 million/km² [2]. During the various stages of exploration, equipment like Pressaug free fall grab (FFG), van Veen grab, box corer, spade corer, dredges, etc. have been used for spot and bulk sampling [7]. Further, accurate mapping of the sea floor and the estimation of reserves were also carried out using advanced equipment like Hydrosweep and Deeptow systems [6]. The disposable ballasts of the FFG and the wire ropes lost during the exploration process lie strewn on the ocean floor on the carpet of polymetallic nodules. Along with this, other artifacts like sunken ship, under-water cables, etc. also lie on the sea floor. These materials could pose a major problem at the time of mining. The hazards involved and their implications to future mining operations are discussed in this paper. In a deep ocean mining system it is mainly the mining head (nodule collector) which is prone to be damaged while encountering an artifact. To reduce the down-time of mining operation in the event of collector breakdown, the idea of free diving mining collector, working in combination with the buffer and riser is put forward.

SURVEY AND EXPLORATION

The exploration for PMN reserves was carried out from 1981 onwards in the Central Indian Ocean. A number of Indian and foreign vessels were used for estimating the reserves of the nodules in terms of abundance, grade and topography. Pressaug free fall grab with a photo camera attachment was used extensively for abundance and grade determination. The free fall grab uses two disposable C.I. weights for its descent to the seabed and collects nodule samples from an area of 0.13 m^2 and surfaces with the help of buoyant glass spheres. Bulk samples were collected from the seafloor by dragging large dredges with a variety of trapping techniques [5] for metallurgical analysis. Apart from these, corers and grabs were used to collect sediment samples. Other standard off-the-shelf equipment were used to collect environmental data.

Nearly 20000 cast iron ballast weights (size $270 \times 140 \times 89 \text{ mm}$), as a result of over 9000 FFG operations in CIB, lie strewn in the potential mine site. In addition, some of the FFGs which are lost during sampling also lie at the mine site. The free fall grab operations were carried out in a grid pattern starting with 60 nautical mile (one degree latitude/longitude) interval in the preliminary survey to 10 km. interval in the high abundance area. Hence, for every $60 \times 60 \text{ sq. mile}$ there are more than 800 ballast weights on the seafloor. Considering an allowable loss rate of 2% freefall grabs itself, 8 freefall grabs are also likely to be there. Free fall corers used for sediment collection leave their ballast shroud on the seafloor. Despite strict precautions, dredges of various sizes (approx. $2\text{m} \times 1\text{m} \times 0.5\text{m}$) lost during bulk sampling lie at the potential mine site. Steel wire ropes of 18 and 10mm diameter in various lengths reaching up to 5000 m lie on the seabed.

Exploration was also carried out in the Indian Ocean by other countries like France, Soviet Union and Germany. Although the losses by these countries have not been reported, the equipment and the wire ropes lost by them in the process of exploration also pose a threat. Unreported number of sunken ships are also present at the seafloor.

IMPLICATIONS

Most of the design concepts of the mining system involve an active or a passive collector, a buffer comprising nodule crusher and an array or riser pipes to pump the nodules to the surface [1]. The different mining collectors proposed by various consortia have incorporated obstacle avoidance sonars, underwater video cameras and special sieves to pick only the required size of the nodules without sediment and avoiding the bulky rocks. The length of the entire mining assembly varies from 5000 to 6000 m. In an operating depth of 6000 m, if the mining collector has to move at the rate 0.5m/sec (30 tonnes/h of mining speed) on the seafloor, the ship should move 400 m in front of the lower end. In case of a problem, it would take more than 10 min to bring the collector to stop.

The threats posed by the mining collector are:

- 1) The ballast weights certainly call for a proper collector design to avoid the weights from entering into the collector.
- 2) The dredges, free fall grabs and the sunken ships may not pose a major problem due to their bulky nature. But it definitely calls for a through study of the seafloor with deeptowed TV cameras and sonars to demarcate these locations on the map as hazardous regions. The mining system should be designed in such a way that it can be moved away rapidly on detection, as the loss of the dredge is usually associated with the loss of steel wire rope.
- 3) The steel wire rope poses a major threat to the mining system. Varying lengths of steel wire ropes are lying embedded on the sediment, which can go unnoticed in the preliminary survey. If they get entangled with the collector, the outcome would be catastrophic, resulting in a high down-time of the mining system. The wire rope can paralyze the movement of the collector and can cause damage to its nodule sorting system and accessories. Ironically, the rate of loss of dredges and wire rope will be high in high abundance areas, where bulk samples were carried out for metallurgical studies. Hence, the expected frequency of breakdown due to an artifact is high.

In the light of the above threats in real time mining, the collector could have a system of rejecting the ballast weights, but still the risk of a mining collector breakdown as a whole or in a subsystem is very high. The presence of ballast weight invites a careful approach to the design of mining collector. The design of water jet pick up is preferable to a rotary cutter type. The cutting edge coming in contact with the ballast weight is liable to be damaged. Even if a back-up system for vital sub-system is incorporated, the danger that a collector might become redundant at the seabottom in the midst of mining operation is very real.

A mining collector breakdown will mean lifting the entire assembly of riser pipes, buffer unit and the collector, servicing the system and redeploying it into operation. It has been estimated that it would take a minimum of 10 days for the above task [2]. The danger assumes magnified proportions in commercial mining, where the estimated mining efficiency is expected to be of the order of 500 tonnes per hour. Such a serious event cannot be tolerated, as it might offset the profitability of the entire mining operation as such.

PROPOSED NEW CONCEPT

The new idea put forward is a modification of the shuttle mining system concept already field tested by the French consortia. The problems associated with the shuttle mining are: (1) Self-contained power package for travelling and mining and (2) acoustic controls and telemetry of real time mining parameters. As a

extension of this idea the collector may be made in two parts: (1) the actual collector unit (Fig.1) which is prone to be damaged by the artifacts and adverse mining conditions (the collecting or sweeping systems, traction systems and steering units). (2) The support system (Fig.2) for the collector like sonars, TV cameras, acoustic controls, crushing and slurring units, etc. The support unit is connected to the end of riser, which is part of the ship's mining system.

Unit 1 and 2 are to be made detachable and the support system is placed at an optimum height for the forward-looking cameras to get a proper view of the seafloor. During normal operation, the units are interlocked together and function as a single collector unit (Fig.3). The detachable collector unit could have the following facilities:

- (a) Variable buoyancy from negative to positive with seawater as ballast
- (b) Acoustically controlled thrusters and transponders
- (c) Power supply for the tasks "a" and "b"
- (d) Cost effectiveness to be expendable in the event of a major breakdown on the seafloor.
- (e) The mining vessel should have one or more collectors as standby and ready for deployment, so that, in case problems arise with the one in operation, the standby collector can be deployed and attached to the support unit and mining can continue with the new collector. The number of standby collectors is dictated by the the expected frequency of breakdown. It may

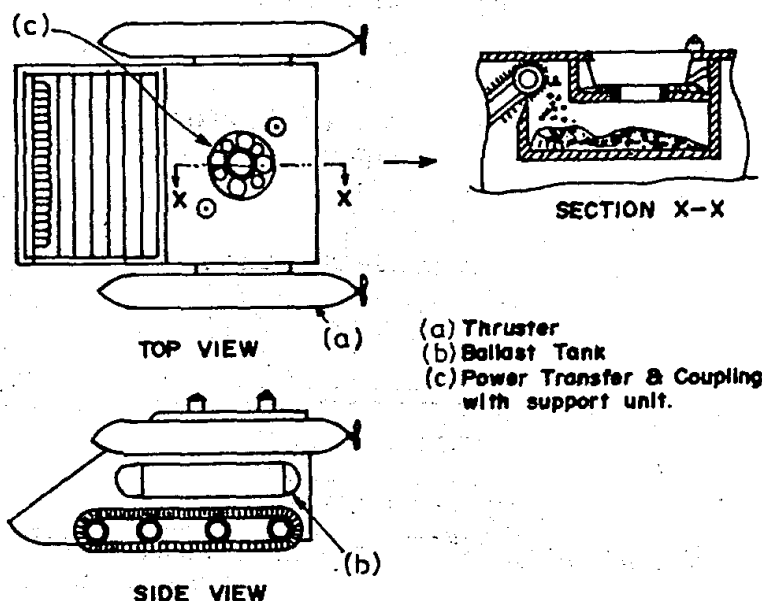


Fig.1 — Collector unit

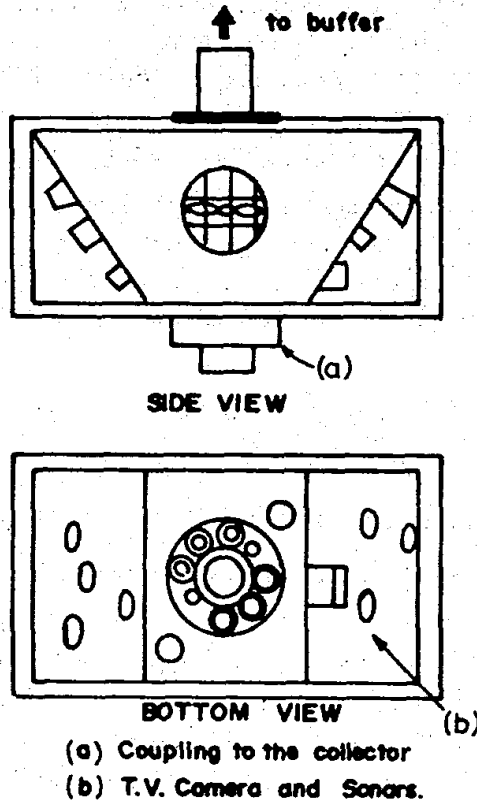


Fig.2. — Support unit

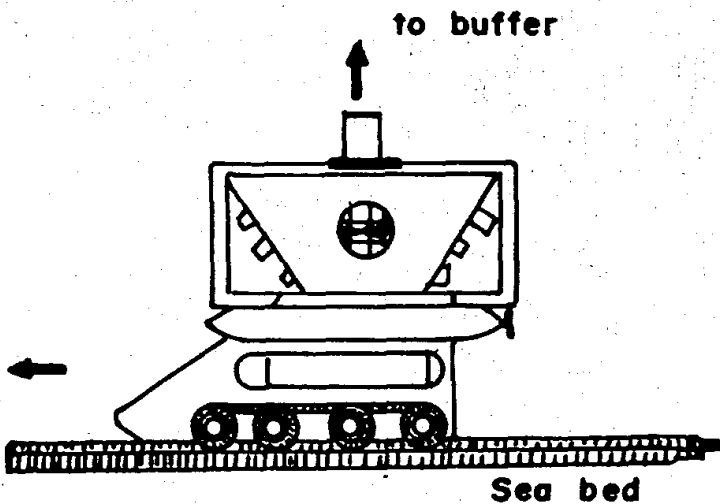


Fig.3. — Support unit coupled with collector

be designed in such a way as to dock one of the standby collectors near the buffer unit, which would cut down the down-time of mining activity drastically. The buffer unit is normally placed at a height of 50 m from the seafloor.

In the event of the collector encountering an artifact resulting in a major breakdown so that further mining is not possible, the collector unit is detached from the rest of the mining system and can be made to surface on its own buoyancy. The standby unit can be sent down to the seafloor. The thruster in the support unit of the main mining system and those provided in the collector unit can be manipulated and the collector attached to the support unit. The coupling of both the units can be devised on the same lines as in the well head re-entry techniques using acoustic controls.

The collector system can have its power transfer from the ship through mechanical lock-in-out couplings, fluid couplings, etc. for its primary traction, collecting and sieving processes. The disabled collector can be propelled and maneuvered acoustically from the seafloor by its own thrusters and brought on board for repairs. Alternatively, the tasks of detaching the collector, fitting the standby collector and retrieving the disabled one can be accomplished by manned submersible.

CONCLUSION

Since nodule deposits represent large dimensions and are distributed over large areas, exploitable best portions have to be selected with care. The entire area to be mined must be seen visually by underwater visual techniques. Based on the exploration data and the data from a seafloor mapping system and underwater television cameras, an obstacle map of the mining area showing the artifacts should be prepared, and a least obstacle path should be arrived at for commercial mining. Image analysis techniques to map the inaccessible topography and plan the probable mining path of the collector and the ship in a particular region should be done as reported earlier [4]. Since loss of wire rope, dredges, etc. is a common phenomenon for any country carrying out such exploration anywhere in the ocean, these factors should be taken into consideration during the design of mining system.

With the proposed new collector design, a continuous mining path in a particular mine site can be established. This will be of advantage in the case of major foul up of the collector with an unsuspected coil of wire or any such thing getting entangled with the moving parts. It will work out more economical to replace only the collector directly at the seabottom and continue with mining rather than bringing up the entire mining system for repairs.

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