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# - JAMSTEC/DEEP TOW CAMERA SYSTEM

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JAMSTEC operates the JAMSTEC/Deep Tow Camera System to conduct pre-site-surveys for the manned submersible "*SHINKAI 2000*". The vehicle is towed by double armored coaxial cable (RG-8/U) of 4500m length and is equipped with the following instruments:

- high quality color video camera for precise seafloor observation. The video image is recorded by S-VHS VCR.
- monochromatic video camera. This camera works alternatively with color camera by command from deck unit.
- four 250W halogen lamps for illuminating the seafloor.
- snap-shot TV camera for monitoring forward obstacles independently of the color camera. This camera records monochromatic still images that are synchronized with strobe fire every 9 seconds.
- tow pairs of still camera and strobe for taking stereoscopic photographs .
- CTD(Conductivity, Temperature and Depth) sensors for improving accuracy of underwater position fixing of the vehicle.
- altimeter for measuring the altitude of the vehicle from sea floor.
- release mechanism for deploying scientific instruments on the seafloor.

The dimension of the vehicle, made of iron pipes, is 2.6m(L)x1.2m(W)x1.2m(H) and total weight is approximately 800kgf in air.

The color composite video signal is converted to an FM signal with central frequency of 6.15MHz because it is very difficult to compensate completely for the transmission loss of video frequency through the coaxial cable. The data from the CTD sensors and the altimeter are displayed with date and time on the monitor screen in real time. Temperature data has proved very important in finding hydrothermal anomaly phenomena. Two years ago, our research group found an active chimney at North Fiji Basin during cooperative cruise between FRANCE and JAPAN. Last year, we deployed long-term hydrothermal observatory system in the same area using this Deep Tow Camera System. Future plans are to construct a new Deep Tow Camera System, towed by fiber-optical cable, to operate at depths greater than 6000m.

JAMSTEC/DEEP TOW CAMERA SYSTEM

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## 1. Introduction

In 1977, JAMSTEC developed the first *JAMSTEC/ Deep Tow System* [1] to findartificial objects such as low level radio active waste package on the deepseafloor at 6,200m depth. The underwater vehicle was equipped with a monochromatic video camera, a still camera, a 100kHz side scan sonar, a 3.5 -7.0kHz sub-bottom profiler, and an acoustic transponder[2][3]. The entire system was towed by a double armored 7,800m coaxial cable.

In 1982, the second system was developed to conduct pre-site-survey for the Japanese 2,000m manned submersible *"SHINKAI 2000"*[4]. At that time, the system was separated into a camera system and a sonar system for ease of operation and maintenance. The depth capability of these systems is 3,500m. Each stage of the *Deep Tow Camera System*[5] development represented state-of-the-art deep sea video camera survey technology. The system has been modified every year to get better quality color video image and to add environmental sensors. In 1988, we lost the vehicle during a North Fiji Basin cruise when it collided with an overhanging rock criff. To avoid future accidents, the replacement vehicle was equipped with a snap-shot TV to monitor faraway obstacles.

At present, the*Deep Tow Camera System* is indispensable for deep sea research at JAMSTEC. Many significant engineering and scientific results have been obtained by this system. In this paper, we will introduce and describe various aspects of the *JAMSTEC/Deep Tow Camera System.*

## 2. Video Signal Transmission

The reception at depth and transmission to the surface of color video images is the basic purpose of the *JAMSTEC/Deep Tow Camera System*. Passing through a coaxial cable, a signal is attenuated exponentially as the frequency increases. Fig.1 shows characteristic signal transmission loss of the coaxial cable (RG-8/U) used for towing the underwater vehicle. On the other hand, broad frequency band width, such as 50Hz∼4.2MHz, is required to transmit the NTSC color video composite signal. If the loss is not compensated for completely, resolution of the image will suffer and color will fade. However, it is very difficult to design an equalizer to fit the characteristics of the towing cable up to 4.2MHz.

In order to avoid the loss,the video signal is converted to FM signal with a central frequency of 6.15MHz and transmitted to the surface deck unit. The FM signal can be demodulated completely even if the attenuation is not fully compensated for. The upper side band of the FM signal is cut by a band-pass filter that is in the sub-surface electronics. The upper and lower cut frequencies of the filter are 7.0MHz and 1.5MHz, respectively. The signal that is transmitted through the coaxial cable is restored completely and demodulated to the standard composite video signal at the deck unit.

## 3. Components of the System

The towed vehicle is equipped with video and still cameras, acoustic transponder and other equipment and is located at the tow cable termination. It is easier to keep the vehicle very close to the seafloor with this design than with the depressor towing method, where a neutral buoyant vehicle is towed behind a depressor. The dimension of the vehicle, made of iron pipes, is 2.6m(L) x 1.2m(W) x 1.2m(H) and total weight is approximately 800kgf in air. The towed vehicle is shown in Fig.2

| Model | JVC,KY-20 |
|---|---|
| element | 2/3" 3CCD |
| horizontal resolution | 530 lines |
| mim. luminous intensity | 23lux with F1.7 lens |
| S/N ratio | 58dB |
| power | DC12V, 1.5A |
| weight | 3kgf. |
| lens | 6.5mm, F1.7 |
| field angle | 80deg. |

Table 1. Specification of color video camera.

The main observation instrument is a high resolution color video camera made by JVC. The specification is shown in table 1. A carrying handle and a view finder of the camera were cut off in order for it to fit in a pressure canister with inner-diameter of 187mm. Four 250W halogen lamps, developed by our lab, are used for illuminating the seafloor.

Two pairs of still cameras, BENTHOS model 372, and strobes, model 382, are installed in the vehicle to take stereoscopic photographs. Each camera can be actuated remotely from the deck unit and take 800 photographs from one film loading (100 feet).

A temperature profile is used to improve accuracy of underwater position fixing of the vehicle, which is navigated by the acoustic transponder, because sound velocity varies depending mainly on the temperature of a medium. Temperature and conductivity are also essential to finding hydrothermal anomaly phenomena on the seafloor. Therefore, CTD (Conductivity, Temperature and Depth) sensors are installed. The temperature probe can be extended to the foot of the sled by a 3m long cable to detect small variations near the seafloor. CTD data are converted to the Phase Shift Keying (PSK) signal of 9.6kHz and transmitted to the deck unit with other data. The signal is demodulated to the binary numbers, processed to the ASCII format by a personal computer, (PC-9801:NEC), recorded by a floppy disk and superimposed on the color video image of the seafloor. The specification of the CTD sensors are shown in table 2. These data are printed out graphically by a XY-plotter during playback.

It is necessary to measure the distance between the cameras and the seafloor if we want to estimate the size of the object on the seafloor by the video image or the photograph. The altitude of the vehicle is, moreover,used for making the precise bathymetric profile along the deep tow track. The altimeter emits seven short acoustic pulses of 118kHz in every second and measures the travel time of the sound. These data are converted to the Frequency Shift Keying (FSK) signal of 250kHz±15kHz and transmitted to the deck unit. The altitude data is also superimposed on the color video image along with the CTD data. The measure range and the resolution are 30m and 2.5cm, respectively.

Since 1987, the *JAMSTEC/Deep Tow System* has been used in the Japan- France cooperative study on the rift system in the Pacific conducted in the North Fiji Basin. In 1988, we lost the vehicle when it collided with an overhanging rock criff. To avoid future accidents, the replacement vehicle was equipped with low-light video camera to monitor forward obstacles. This camera is used alternatively with the color video camera by command from the deck unit, because there is only one transmission channel for video signals. Because sites that are very dangerous for *Deep Tow* are geologically more interesting than flat and muddy areas,it is scientifically counter- productive to change the camera for forward monitoring during observations of rock cliffs and other irregular hard-surfaced areas.

Therefore, a snap-shot TV camera was developed to monitor faraway obstacles. This camera takes a momentary image illuminated by strobe flash and sends it to the FM modulator which is attached beside the color video camera. One frame (equals two fields) image of the main color TV is replaced by the snap-shot image at a pre-stage of the FM modulator. At the same time, an index signal is inserted between the previous image and the one before that. At the deck unit, as shown in Fig 3, a signal freezer searches the video signal sent from the vehicle for the index. When the index is detected, the image after next one is extracted and frozen by the frame memory and displayed on the TV screen until next new image arrives. At the same time, the blank in the main color TV image is filled with the same image as the previous one. Therefore, both

| Model | SONY,XC-77 |
|---|---|
| element | 2/3" CCD |
| horizontal resolution | 570 lines |
| mim. luminous intensity | 0.5lux with F1.4 lens |
| S/N ratio | ≥50dB |
| power | 10.5~15.0V, 2.2W |
| size (mm) | 44(W)x29(H)x107(D) |
| weight | 190gf. |
| lens | 16mm, F1.4 |
| strobe power | 230W/sec |

Table 3. Specification of monochromatic TV camera.

| Items | Conductivity | Temperature | Depth |
|---|---|---|---|
| range | 1~65mmho/cm | -2~30°C | 0~6,300m |
| resolution | 0.001mmho/cm | 0.001°C | 0.1m |
| accuracy | ±0.05mmho/cm | ±0.025°C | ±0.25%FS |
| sensor type | electro-magnetic induction cell | platinum thermister | strain-guage |

Table 2. Specification of the CTD sensors.

images of the main color TV and the snap- shot TV are transmitted simultaneously through a coaxial cable. The specification of the TV camera and the strobe are shown in Table 3. By our experiences, it was best to set the strobe faced in an up and forward direction to illuminate forward obstacles with back-scattering light. An example screen of the snap-shot TV is shown in Fig. 4.

In addition, the vehicle is equipped with an electric releaser to drop a sediment sampler or deploy scientific instruments. In 1989, we deployed the *Long-term Hydrothermalism Observation Station* (LHOS) very close to the active chimney at the North Fiji Basin while we observed the seafloor with the color video camera. The *LHOS* was recovered four weeks later. The dimension of the *LHOS*, equipped with a still camera, a strobe with a battery and a controller, a CTD, a current meter and an acoustic transponder, is 2.0(W) x 2.3(L) x 1.5(H)m. The *LHOS*[6] that is held under the vehicle is shown in Fig. 5.

A precise underwater position fixing of the vehicle is very important for a deep seafloor survey. Since 1977, we have studied acoustic transponder navigation for application and operation at 6,000m depth. At first, the system was purchased from ORE (U.S. company). Taking our experiences into account, a new system has been developed by OKI and is now used on all our ships: the mother ship *"NATSUSHIMA"* of *"SHINKAI 2000"*, the semsubmerged catamaran *"KAIYO"* and the mother ship *"YOKOSUKA"* of the new submersible *"SHIN KAI 6500"*[7]. The *JAMSTEC/Deep Tow System* is navigated by SSBL (Super Short Base Line) acoustic positioning system, that is not necessary to put transponders on the seafloor such as LORAN C or GPS. The accuracy of the SSBL system is approximately 1.5% of a slant range and it is enough for a Deep Tow survey of a wide area[8].

## 4. Operation

The deck unit of the *JAMSTEC/Deep Tow Camera System* is housed in a container van with all peripherals including winch controller for the towing cable. The van, which is 2.3 x 6.0 x 2.1m, cable winch, and 4,500m cable can be loaded on a ship's deck. Hydraulic power for the winch is supplied by the ship.

Gimbal mechanism, sheave, specially designed for towing the vehicle, is attached on the top of a stern A-frame crane[9] ,as shown in Fig 6. The sheave does less damage to the tow cable and also measures all towing cable status such as length of cable payed out, tension, and three dimensional towing angle. The data are processed by a personal computer and displayed graphically on the CRT screen.

Maneuverability and position fixing accuracy of a ship are especially important to guide the towed vehicle on the intended line. Our ships have excellent maneuverabilities at even slow speed, because of precise surface and underwater positioning systems. In particular, the SSC *"KAIYO"* has a capability to steer any direction at low speed by use of bow and stern side thrusters. Therefore, the *Deep Tow System* can be operated even in rough sea conditions.

The *JAMSTEC/Deep Tow System* is generally operated by four to six members of the Deep Sea Research (DSR) group. This team checks, preforms and repairs the system. Launching and recovering of the vehicle and winch operation are carried out by the ship's crew. A winch man controls the vehicle, which is towed at an approximate speed of 1kt, to keep a height of 2 to 5 meters above the seafloor, depending on the mission.

The *JAMSTEC/Deep Tow System* has carried out not only pre-site- surveys of the *"SHINKAI 2000"* but also deep seafloor surveys of more than 2,000m around the Japanese Island. The surveys amount to ten weeks, which equals about 3 cruises, every year on average. About half of them are the cruises using the multi-nallow beam echo-sounder, that is *"SEA BEAM"* and the rest are the Deep Tow survey. The DSR group has also participated in international cooperative cruises with the system and ship. We have carried out more than sixty-five deep tow cruises up to now and the following are some of the significant findings:

(1) In 1983, a big submarine earthquake (M7.7) occurred in the central Japan Sea water depth around 3,000m. Many cracks, small fissures, dead fishes and yellowish deposits were found on the seafloor. Next year, the deposits were sampled by the box dredger which was hung under the vehicle [10].
(2) In 1986, biological communities of giant clam and tube worms were found in the Sagami Trough, 40 nautical miles south west from Tokyo. After that, other communities were also found in the opposite side of the trough axis.
(3) In 1987, biological communities of giant clam, white crab without eyes and other animals were found in the submarine volcano Kaikata Seamount in the Bonin Islands. The crabs were sampled and reared in a small tank for one year.
(4) In 1987, hydro-thermal activity, with associated biological communities, was found in the north of the North Fiji Basin[11].
(5) In 1988, hydro-thermal activity was found in the Okinawa Trough.
(6) In 1989, Biological communities of giant clam, tube worm and other animals were found in the Nankai Trough during pre-site-survey for the French submersible "NAUTILE" that was conducted by Japanese and French organizations.

## 5. Summary

Clear visual information is very important for deep sea geological and biological surveys. JAMSTEC operates manned submersibles and the unmanned ROV, called *"DOLPHIN 3K"*[12], for the observation of the seafloor, but they requires many operating staffs and large budgets. The major advantage of the *JAMSTEC/Deep Tow System* is that it can be operated by fewer staff and it is less expensive.

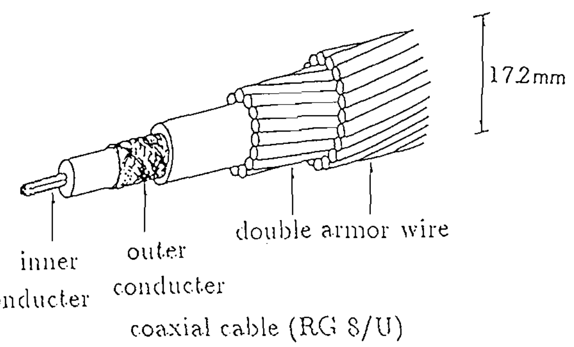
We are designing a new *Deep Tow System* towed by a fiber- optic cable to conduct pre-site-survey for *"SHINKAI 6500"*. The system will be equipped with two color video cameras, a gyro-compass, a long range snap-shot TV and a small ROV which can be launched from Deep Tow. We hope, hereafter, the *JAMSTEC/Deep Tow System* will be used more frequently for scientific achievement and effective and safety diving.

## 6. Acknowledgment

We thank the member of Deep Sea Research group in JAMSTEC, who assisted in developing and operating the *JAMSTEC/Deep Tow System*. We also thank the engineers of Shyonan High-frequency Laboratory who assembled the *JAMSTEC/Deep Tow Camera System* according to our design. The study of the first Deep Tow System was sponsored by Bureau of Atomic Energy of Science and Technology Agency. Thanks also to Greg Stone for reviewing this manuscript.

## 7. References


1. Hotta,H. et al. "Preliminary sea trial of deep sea floor survey system", JAMSTECTR (Technical Report) (5), pp27-44, 1980
2. Otsuka,K.,Nakanishi,T. and Hotta,H. "Deep Tow Sonar System", JAMSTECTR (8), pp1-28,1982
3. Nakanishi,T. et al. "Laboratory and at sea tests on Long Base Line Acoustic Navigation System", JAMSTEC (3), pp39-49, 1979
4. Takagawa,S. et al. "Japanese 2000m Submersible Research Vehicle *SHINKAI 2000* System", OCEANS'81, pp1155-1159,1981
5. Otsuka,K. et al. "Development and Operation of the Deep-Tow Color Video System", JAMSTECTR (19), pp249-262, 1988
6. Mitsuzawa,K. et al. "Development of Long-term Observation System by means of *JAMSTEC/Deep Tow System*", OCEANS'89, pp 820-826, 1989
7. Nakanishi,T. et al. "Japanese 6500m Deep Manned Research Submersible Project", OCEANS'86, pp1438-1442, 1986
8. Momma,H. and Hotta,H. "Operating Techniques of Deep Towing and Accurate Positioning', Proc. 8th Ocean Engineering Symposium, pp57-62, 1987
9. Momma,H. and Hotta,H. "Development of a Gimbal Type Sheave for Deep Towing", OCEANS'83, pp270-273, 1983
10. Hotta,H. et al. "Visual Observations in the Central Area of the 1983 Central Sea of Japan Submarine Earthquake", JAMSTECTE (14), pp37-53, 1985
11. Honza,E.,Auzende,J.M., et al. "Geology of the rift system in the North Fiji Basin: Results of Japan-France Cooperative Research on board KAIYO 88", La mer 27, pp53-61, 1989
12. Nomoto,M., and Hattori,M. "A Deep ROV *DOLPHIN-3K*,Design and Performance Analysis", IEEE, Jour. Ocean Eng. Vol.OE-11,No 3, pp373-391, 1986
13. Momma,H., and Otsuka,K. "JAMSTEC/ DEEP TOW TOW SYSTEM", OCEANS'88, pp1253 -1258, 1988


Towing double armored coaxial cable

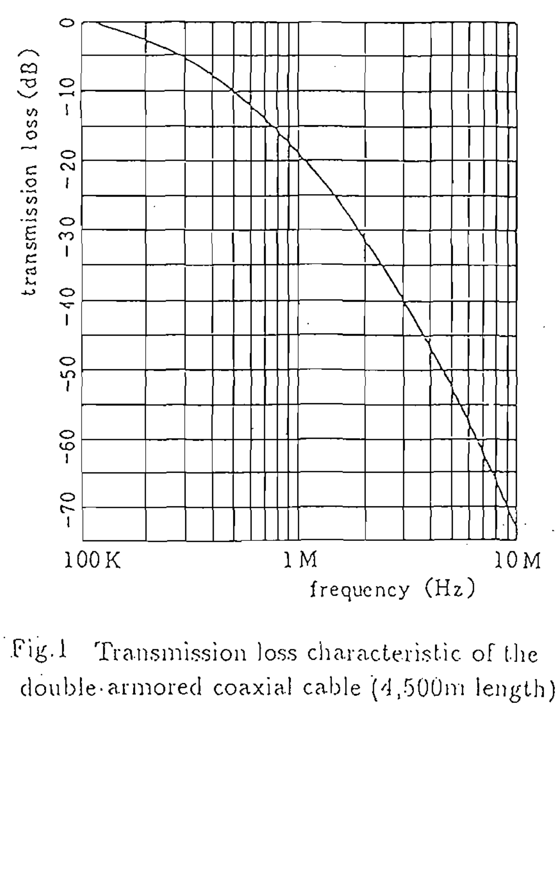



Fig.1 Transmission loss characteristic of the double-armored coaxial cable (4,500m length)

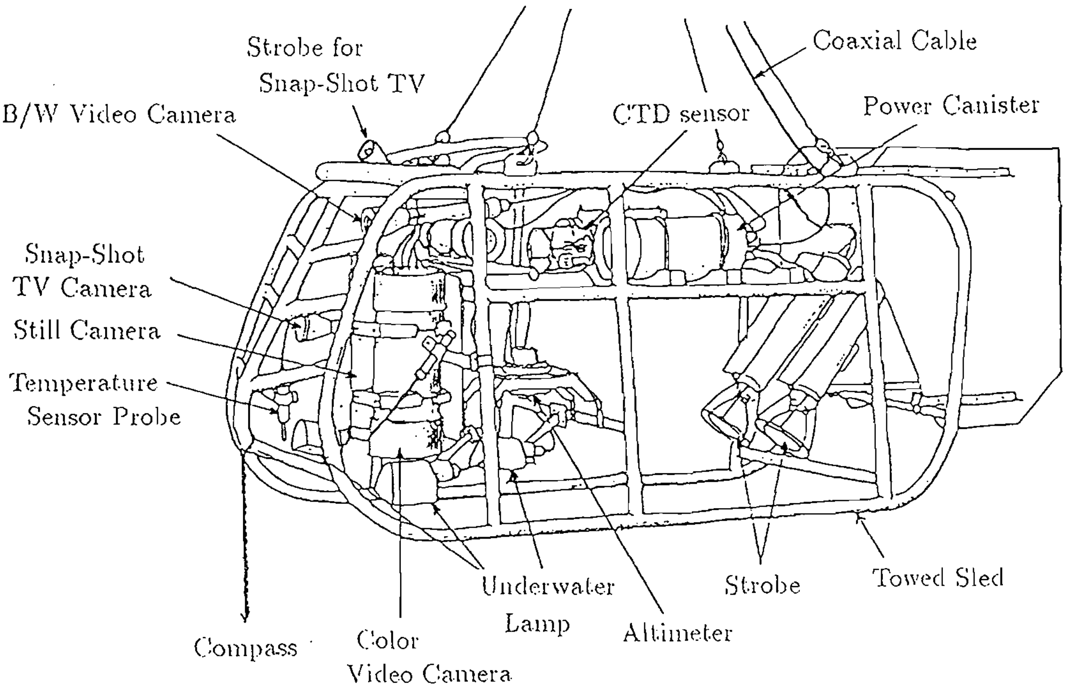



Fig.2 *JAMSTEC*/Deep Tow Camera

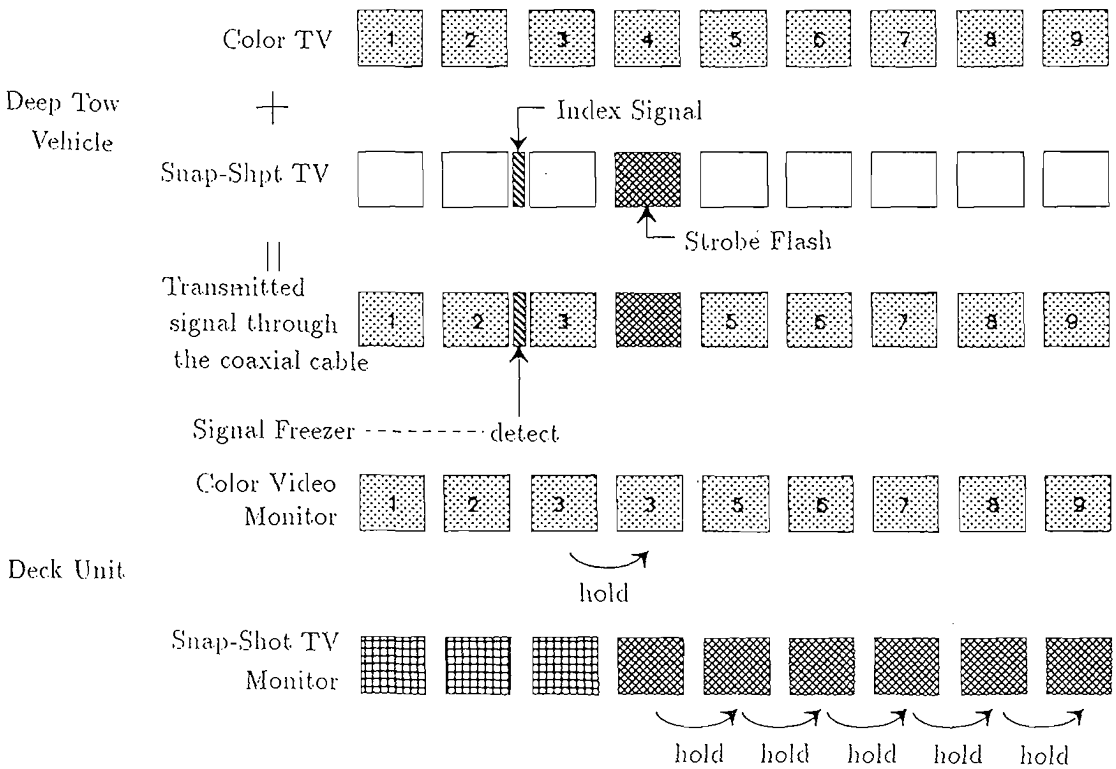



Fig.3 Explanation of transmission of the Snap-Shot TV image

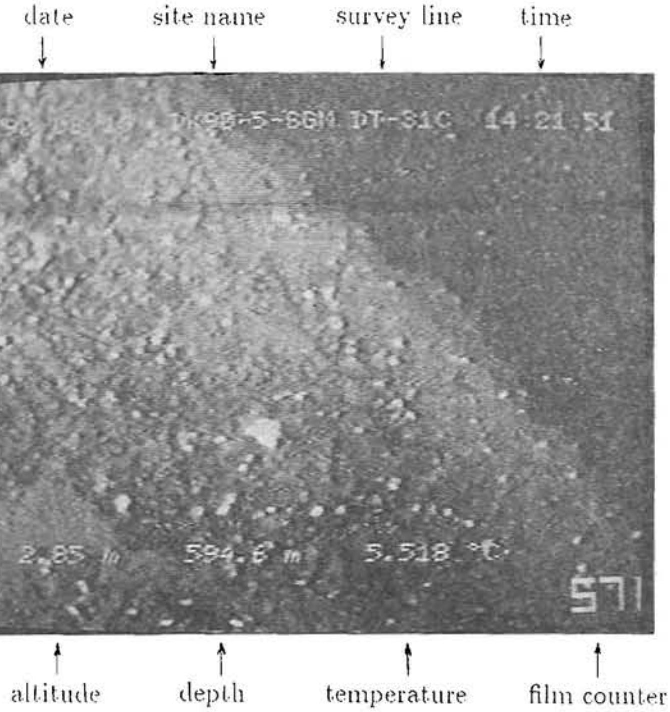



Fig.4 An example screen of the snap-shot TV

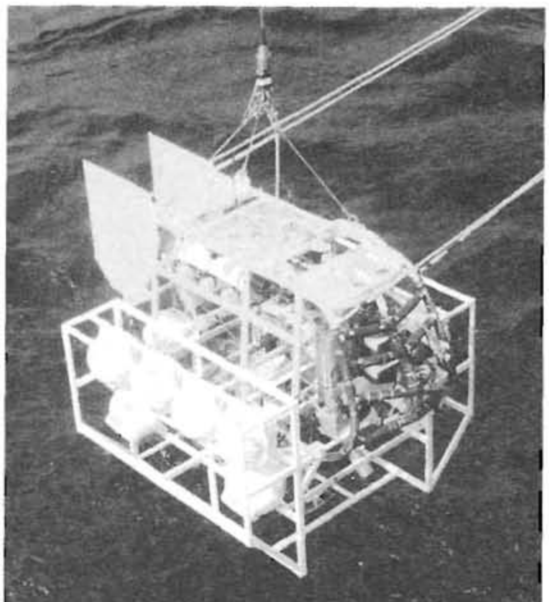


Fig.5 The Long-term Hydrothermalism Observation Station *(LHOS)* that is held under the vehicle

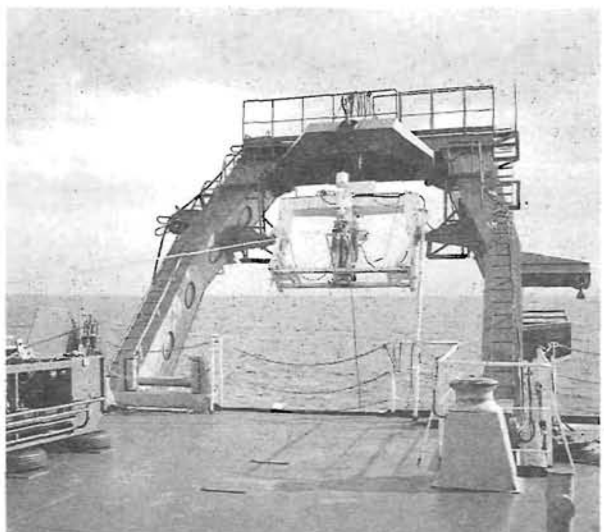


Fig.6 Gimbal sheave is attached on the top of a stern A-frame crane.