I. INSTRUMENTS

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I.1 Sampling tools

I.1.1 Cylindrical type buckets

Four kinds of buckets A. B, C and D (Fig. 2) were used in this cruise. These buckets

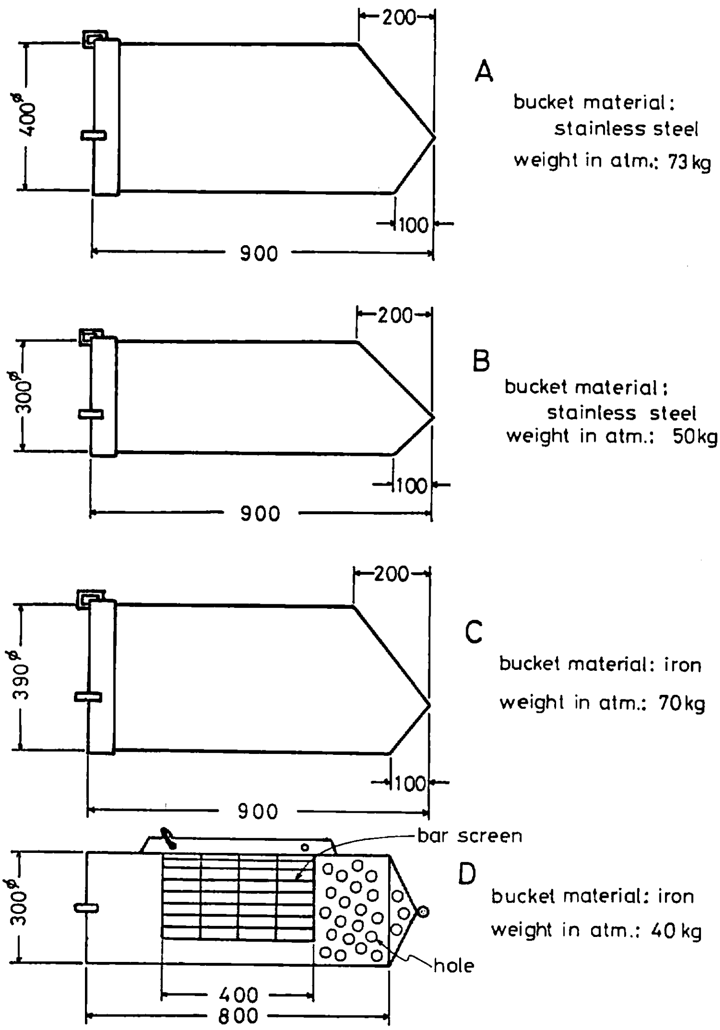

Fig. 2. Cylindrical type buckets.

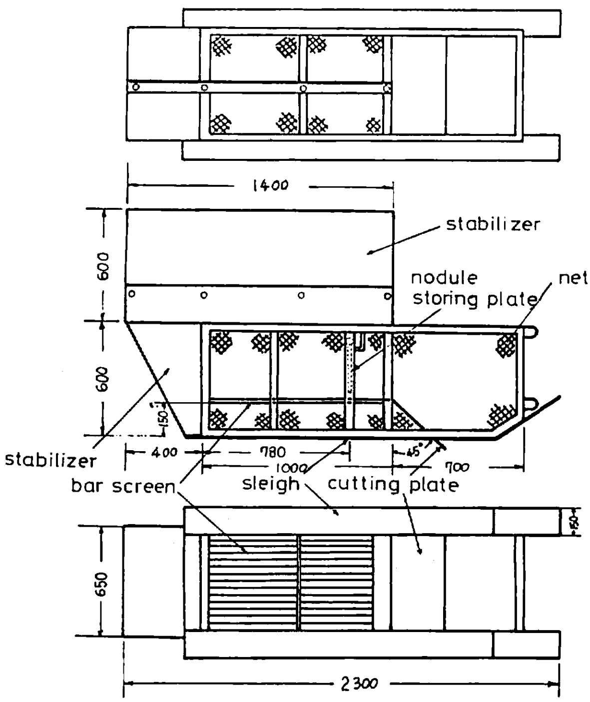

Fig. 3. Box type bucket.

were used selectively for various marine sampling works, for instance A, B and C buckets for soft sediments and D for nodules and rock fragments.

I.1.2 Box type bucket

A box type bucket is shown in Fig. 3. The bucket was manufactured as a trial for sampling manganese nodules on the basis of data obtained from tests in the indoor horizontal test tank. The mechanical characteristics of the bucket are as follows:

a) Sleighs are attached to both sides of the base, so that the bucket can move smoothly on sea bottom without disturbance.
b) Ferromanganese nodules within soft sediments should be caught into the bucket by a cutting plate under the open mouth.
c) Bottom bar screen is installed about 15 cm higher than the sleighs for the better separation between nodules and soft sediments inside the bucket and for the efficient discharge of soft sediments from the screen.
d) The bucket has a free plate inside, which prevents the dredged nodules from escaping through the open mouth during hauling of the bucket from bottom to surface.
e) A controller is necessary for the normal landing of the bucket, because of its asymmetrical structure. For this purpose, stabilizers are set on the rear and top of the bucket (Fig. 4).

The box type bucket is 230 kg (200 kg in water) in weight and $0.23m^3$ in net capacity.

I.1.3 Shipek type grab sampler

The sampler consists of semi-cylindrical frame, coaxial semi-cylindrical scoop, two powerful springs, trigger weight and locking pin. During descent the locking pin holds the scoop in the body frame. When it strikes sea bottom, the trigger weight taps the upper part of locking pin. At this moment the pin releases the lock, and the scoop is rotated into the sediments by the powerful springs and can dig up sediments from an area of 400 cm^2. The size of this sampler is 50 cm long, 60 cm wide and 50 cm high, and the weight is 61 kg in air and 53 kg in water.

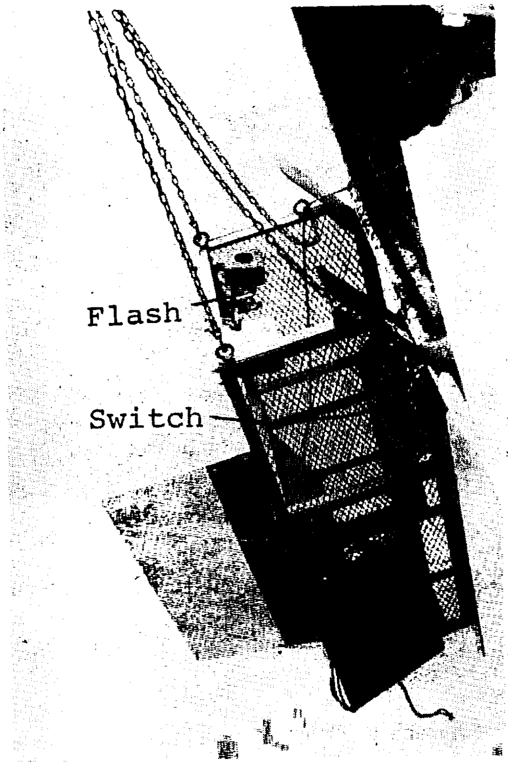

Fig. 4. Box type bucket.

I.2 Instruments for measurements related to sampling

The following instruments were used for the measurement of bucket behavior and variation of wire rope tension in this cruise.

I.2.1 Wire rope tension meter

The apparatus is composed of tri-pulley tension detector, amplifier and recorder. As

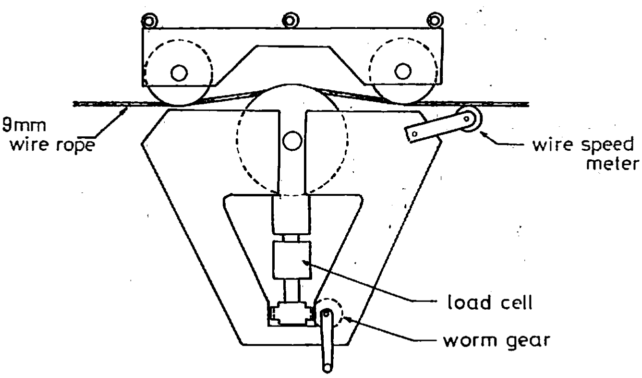

Fig. 5. Tri-pulley tension meter.

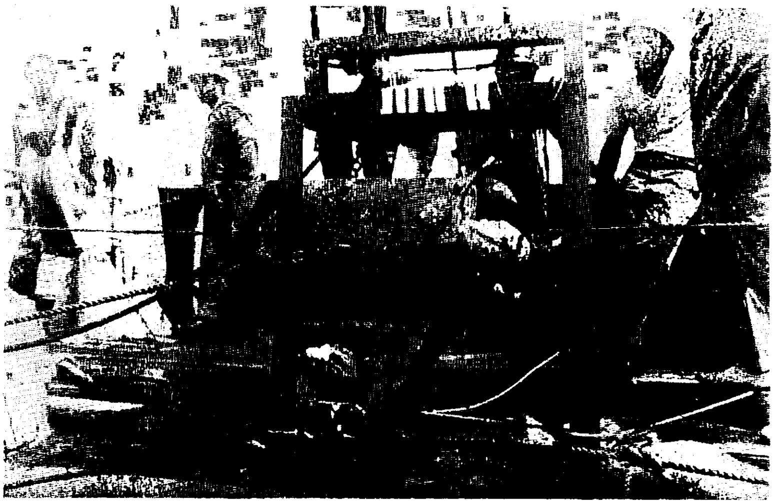

Fig. 6. Tri-pulley tension detector.

shown in Fig. 5, the wire rope passes through the tri-pulley tension detector which detects the tension by the strain gauge type load cell attached to the main pulley. Detected signal is amplified by the strain meter and recorded on a chart. The appearence of this detector is shown in Fig. 6.

I.2.2 Sea-floor bucket tension recorder

The recorder consists of spring, recording tape and tape winding mechanism. The tension, that is converted to the movement of recording needle by the action of spring, is recorded on the tape which is also wound by spring (Fig. 7).

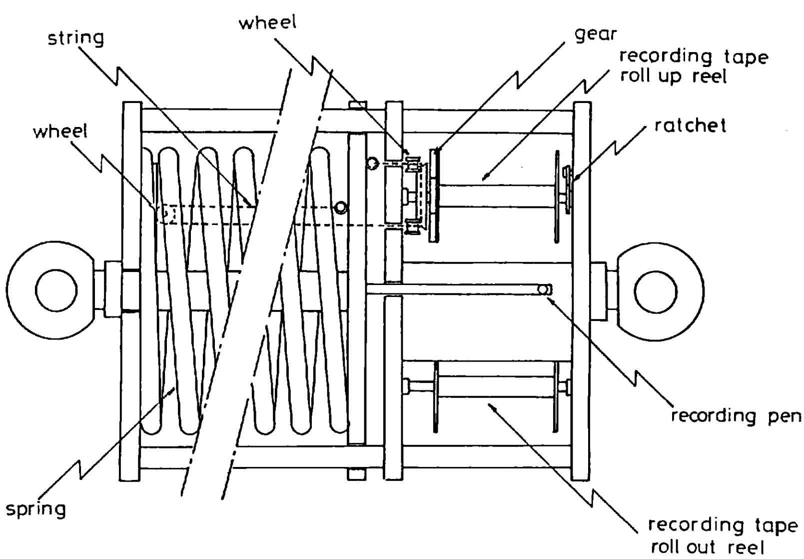

Fig. 7. Bucket tension recorder.

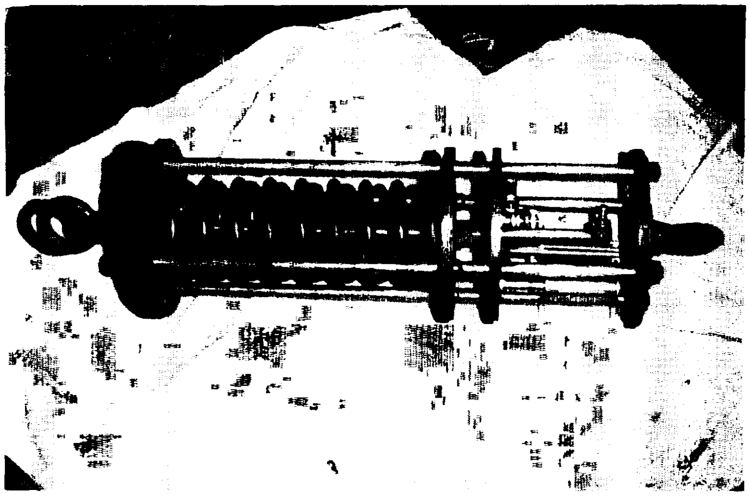

Fig. 8. Bucket tension recorder.

During the cruise, two bucket tension recorders; 500 kg and 1 ton in maximum tension, were used. One of them is shown in Fig. 8.

I.2.3 Arrangement of the instruments

As illustrated in Fig. 9, the tri-pulley tension detector is attached between the winch and the turning capstan on the deck. A wire length meter is attached on the main block of gantry. In order to measure the vertical movement of vessel, a strain gauge type acceleration senser is set on the deck. On the other hand, the 500 kg bucket tension recorder is set between the weight chain and the cylindrical type buckets, and the 1 ton bucket tension recorder between the main wire and the weight chain (Figs. 10, 11).

I.2.4 Deep sea camera

The deep sea camera, developed by Rikagaku-Kenkyusho (The Institute of Physical and Chemical Researches) is composed of camera, strobo-light, sonar pinger, battery and

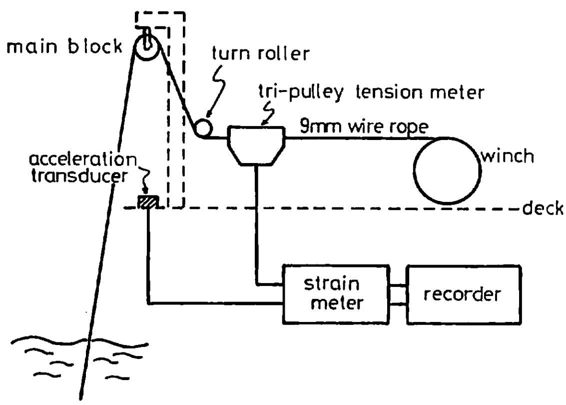

Fig. 9. Measuring method of tension on the deck.

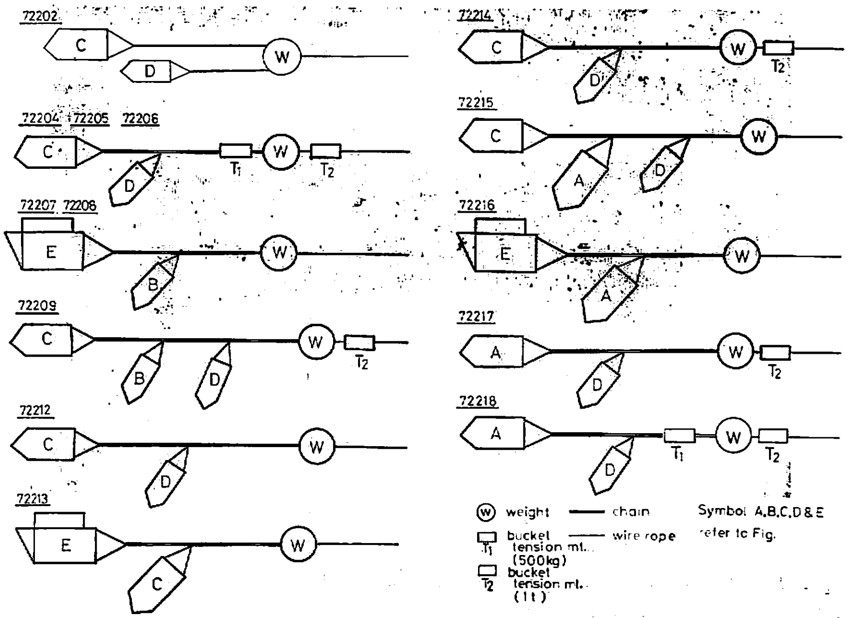

Fig. 10. The arrangement of buckets at each station.

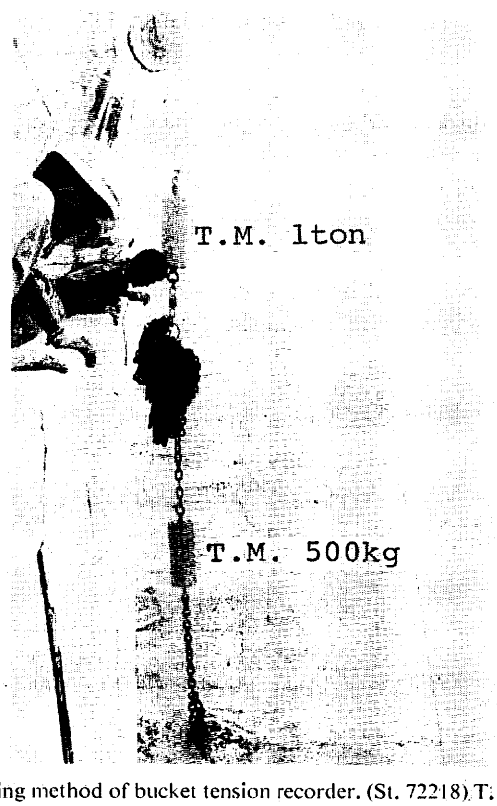

Fig. 11. Connecting method of bucket tension recorder. (St. 72218) T.M.: Tension meter.

bottoming switch, which are respectively set in the pressure proof container and attached on the stainless steel framework. The framework is 125 cm long, 50 cm wide and 105 cm high, and the total weight is 250 kg.

The camera can automatically take 600 photographs of the sea bottom after the weight of bottoming switch strikes sea bottom.

I.3 Works and Results

I.3.1 Work time

Table I indicates the time spent for the works, classified into lowering dragging and hauling at each station. And the relationship between the time and the water depth is shown in Fig. 12. In general, more, dragging time in dredge works is in necessary with the increase of water depth, because of the difficult recognizing the dredging behavior. Consequently, it is true that the difficulty of dredging operation increases with the water depth, but the time spent for dredging is not in simple proportion to the water depth.

I.3.2 Dredging systems

Two or three buckets were set above the chain weight at some distance on the wire rope as Figs. 10 and 13. These buckets were lowered to the sea bottom, and dragged on the seafloor by the natural drift of vessel until the completion of sampling.

In general, it is very important for drag dredging, especially in deep sea, to accurately judge whether the buckets are on-bottoming, dragging or off-bottoming. Therefore, it is

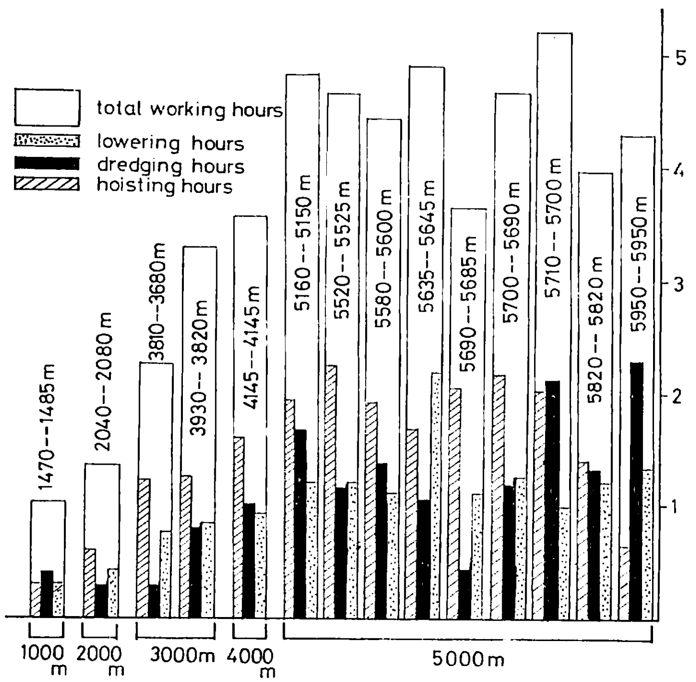

Fig. 12. The relationship between the time for dredging and water depth.

Table 1. Time for dredging.

station No.	water depth (m)	total working hours (min.)	descent-on-bottom working hours (min.)	descent-on-bottom per 1000m (min.)	off-bottom-ascent working hours (min.)	off-bottom-ascent per 1000m (min.)
72201	5790		stoppage of working due to winch trouble			
72202	5160—5150	292	74	14.3	116	22.5
72203	5140—5140	211	89	17.3	89	17.3
72204	5700—5690	278	77	13.5	130	22.8
72205	5950—5950	261	81	13.6	138	23.2
72206	5580—5600	266	69	12.4	115	20.5
72207	5635—5645	297	131	23.2	102	18.1
72208	5710—5700	303	61	10.7	124	21.8
72209	3930—3820	178	52	13.2	77	20.2
72210	1770—1770	53	24	13.6	28	15.8
72211	2010—2010	83	26	12.9	45	22.4
72212	2040—2080	83	27	13.2	37	17.8
72213	5690—5685	221	68	12.0	124	21.8
72214	1470—1485	63	19	12.9	25	16.8
72215	5820—2820	238	74	12.7	84	14.4
72216	5520—5525	287	74	13.4	136	24.6
72217	3810—3680	136	46	12.1	74	20.1
72218	4145—4140	215	57	13.8	97	23.4

*used instruments DR.: dredge bucket, BTR: bucket tension recorder, DSC: deep sea camera
SHIPEK: Shipek grab sampler.

judged by an automatical measurement of wire tension on the deck.

1.3.3 Results

1) Dredge works

St. 72202 (Depth 5.160–5.150m)

The buckets were on-bottom at the wire length of 5,298m, and dragged for about 102 min. by letting the wire out to 5,994m. Large volumes of brown clay with manganese nodules were obtained in D bucket.

St. 72204 (Depth 5,700–5,690m)

The buckets wire on-bottom at the wire length of 6.471 m, and dragged for about 71 min. by letting the were out to 6,882m. Small volume of brown clay in which contained small amounts of ferromanganese nodules were caught in C bucket, but nothing in D bucket.

St. 72205 (Depth 5,950–5,950m)

The buckets were on-bottom at the wire length of 6,796m, and dragged for about 42 min. by letting the wire out to 7,222m. However, no ferromanganese nodules were collected, except a small amount of brown clays in C bucket, at the station.

draging hours (min.)	used instruments*	ratio of each working hours to total working hours (%)			maximum rope length (m)
		descent	ascent	draging	
102	DR. 2 BTR 1	25	40	35	5994
33	DSC 1	42	42	16	5268
71	DR. 2 BTR 2	28	47	25	6882
42	DR. 2 BTR 2	31	53	16	7222
82	DR. 2 BTR 2	26	43	31	6334
64	DR. 2	44	35	21	7247
118	DR. 2	20	41	39	6365
49	DR. 3 BTR 1	29	43	28	4599
1	SHIPEK 1	45	53	2	1853
12	DSC 1	31	54	15	2164
19	DR. 2	33	45	22	2390
29	DR. 2	31	56	13	6260
19	DR. 2 BTR 1	30	40	30	1782
80	DR. 3	31	35	34	6547
77	DR. 2	26	47	27	6487
16	DR. 2 BTR 1	34	54	12	4182
61	DR. 2 BTR 2	27	45	28	5293

St. 72206 (Depth 5,580–5,600m)

The buckets were on-bottom at the wire length of 6,064m, and dragged for about 82 min. by letting the wire out to 6,334m. Large volumes of brown clay, associated with spherical and oblate nodules of 31 kg were obtained in C bucket, and also only nodules of 13 kg in D bucket.

St. 72207 (Depth 5,635–5,645m)

At first the wire was let out to the length of 7,247m equal to 1.3 times of the water depth, but the on-bottoming of buckets was hardly recognized on the recorder. However, the on-bottoming was detected at the wire length of 6,540m when the buckets were hauled up. It seems that the excessive wire length for the on-bottoming of buckets may be caused by a large drift of E bucket, because of strong water current and the shape of rear stabilizer, apted to forward a horizontal movement of the bucket.

Concerning the sampling results, large volumes of brown clay with ferromanganese nodules of 17 kg were collected in B bucket, and spherical and oblate nodules of different sizes of 63 kg in E bucket (Fig. 14).

St. 72208 (Depth 5,710–5,700m)

The buckets were on sea-floor at the wire length of 6,070m, and dragged for about

Fig. 13. Link of bucket, weight chain and bucket tension recorder.

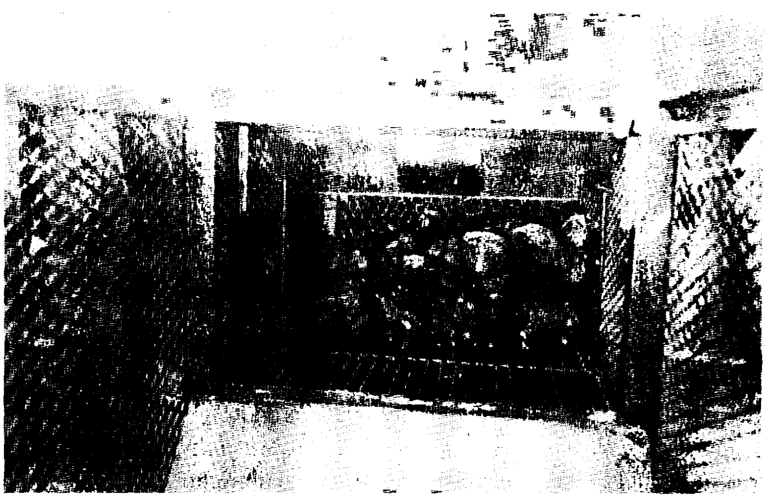

Fig. 14. Ferromanganese nodules dredged in the box type bucket.

118 min. by letting the wire out to 6,365m. Large volumes of brown clay were obtained in B bucket, but nothing in E bucket.

St. 72209 (Depth 3,930–3,820m)

The buckets were on sea-floor at the wire length of 3.930m. and dragged for about 50 min. by letting the wire out to 4,599m. Only a small volume of brown clay were collected in C bucket, but nothing in B and D buckets.

St. 72212 (Depth 2,040–2,080m)

The buckets were on sea-floor at the wire length of 2,050m, and dragged for about 20 min. by letting the wire out to 2,390m. Small volume of calcareous oozes, contained small rock fragments, were obtained in C buckets, and two pieces of volcanic rock in D bucket.

St. 72213 (Depth 5,690–5,685m)

The buckets were on sea-floor at the wire length of 6,000m, and dragged for about 30 min. by letting the wire out to 6,260m. Only a few rock fragments coated with iron manganese oxides were collected in E and C buckets. However, the sea bottom seemed to be rocky at the station, because no soft sediments in C bucket.

St. 72214 (Depth 1,470–1,485m)

The buckets were on sea-floor at the wire length of 1,620m, and dragged for about 20 min. by letting the wire out to 1,782m. A small volume of calcareous ooze, associated with some rock fragments, were obtained in C bucket.

St. 72215 (Depth 5,820–5,820m)

The buckets were on sea-floor at the wire length of 6,252m, and dragged for 80 min. by letting the wire out to 6,547m. Large volumes of brown clay, accompanied by ferromanganese nodules of 80 kg, were collected in A and C buckets.

St. 72216 (Depth 5,520–5,525m)

The buckets were on sea-floor at the wire length of 5,900m, and dragged for about 80 min. by letting the wire out to 6,487m. Large volumes of brown clay, associated with a small amount of nodules, were obtained in A bucket, and also oblate or slab shaped nodules of 6 kg in E bucket.

St. 72217 (Depth 3,810–3,680m)

The buckets were on sea-floor at the wire length of 4,039m, and dragged for 16 min. by letting the wire out to 4,182m. The buckets were encountered with a small hill of 100 m in its height during descent. Large volumes of radiolarian ooze were collected in A bucket.

St. 72218 (Depth 4,145–4,140m)

The buckets were on sea-floor at the wire length of 4,417m, and dragged for about 60 min. by letting the wire out to 5,293m. Large volumes of sandy silts were obtained in A bucket.

2) Sampling by Shipek

The Shipek type grab sampler was used in relatively shallow water of 1,770m at St 72210. Only a small amount of calcareous ooze was obtained because of rocky bottom, as shown in the photographs.

Fig. 15 shows an record of the Shipek on the sea-floor by the wire tension recorder. It is obvious that the tension was largely relieved from the wire length of 1,830m and decreased to the minimum at 1,850m. Accordingly, the Shipek might be landed on the sea bottom at the wire length of 1,850m. Successful results of sampling would be expected if the sea bottom was composed of soft sediments.

It has been questioned that the Shipek can be used in deep water, because of the light weight. However, it was shown by this survey that the Shipek might be useful until the

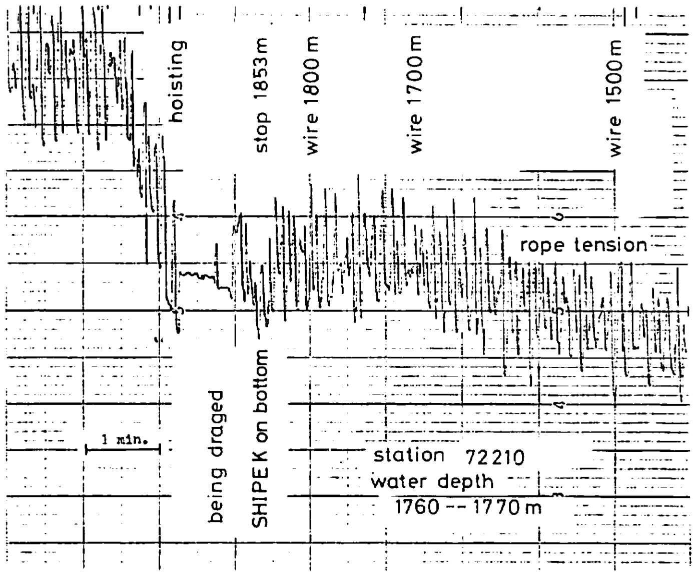

Fig. 15. On-bottom record by Shipek grab sampler.

depth of about 2,000m. The on-bottoming of Shipek would be hardly recognized by the tension meter at a depth over 2,000m. Therefore, additional weight on the Shipek or other tension measuring methods should be necessary for its better application.

3) Measurement of tension

A. Results of wire tension measurement on deck

a) The tension measured by the tension meter corresponds to the sum total of the weight at the end of wire rope (weight of dredge buckets, weight chain and others), the weight of wire rope itself and their fluid resistance in sea water. Moreover, the force of inertia should be added to the tension when the winding speed of wire is changed.

b) Fig. 16 illustrates the variation of tension when the winch was stopped at the wire

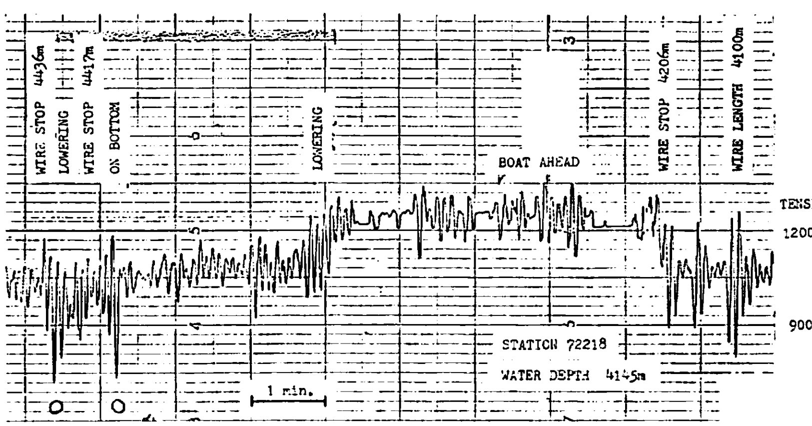

Fig. 16. Recorded charts. (example I)

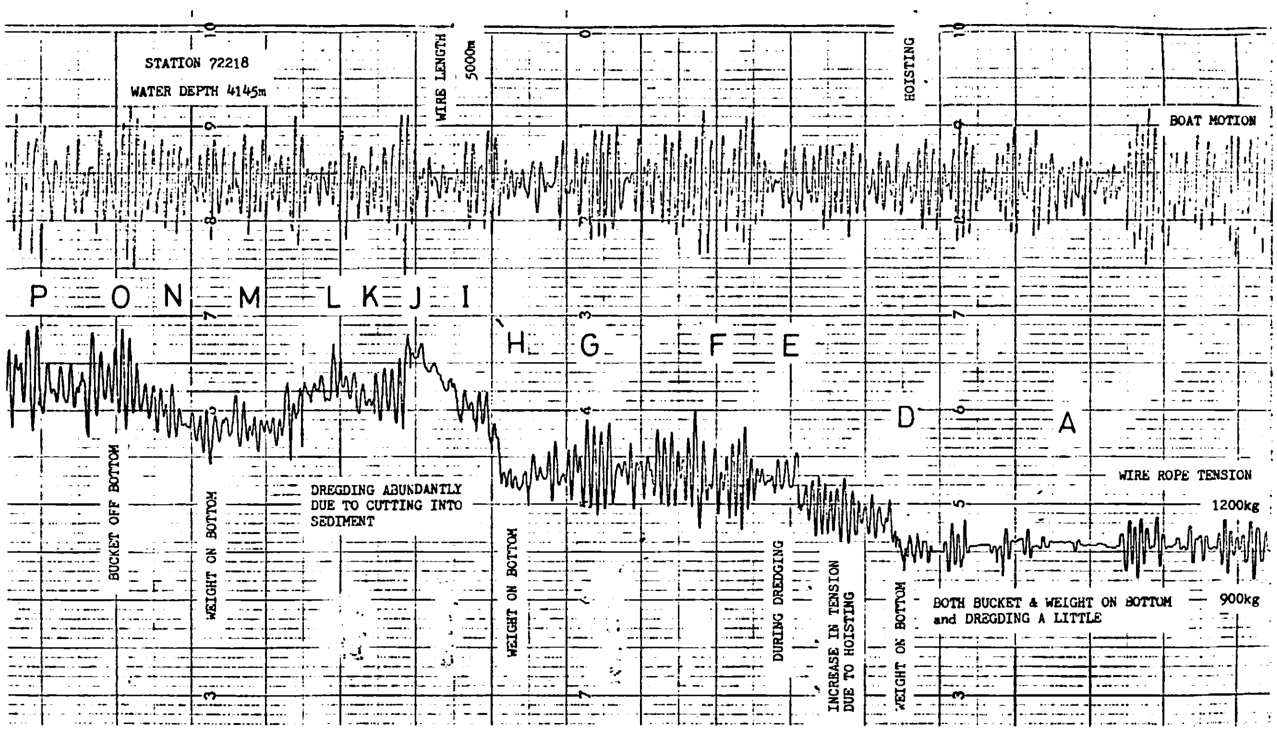

Fig. 17. Recorded charts. (example II)

length of 4,200m during lowering (at St. 72218). After stopping the winch, the wire rope tension increased to 1,210 kg, because the upward fluid resistance decreased. At this moment, the weight at the end of wire rope was 350 kg in water and the weight of wire rope itself was 0.21 kg/m in water (Fig. 10). Therefore, the theoretical value of tension was calculated at 1,230 kg, which approximately agreed with the actual measured value. The tension moderately increased one minute after stopping winch, because of the rise of fluid resistance due to the dead slow movement of the vessel. Then the decrease of tension was observed at the start of rewindout of the rope.

c) When the buckets and/or weight chain were on sea-floor, the decrease of tension was recognized at the mark 0 in Fig. 16. It is sometimes difficult to distinguish the decrease of tension at the on-bottoming from that at the rewindout of wire rope in deep sea. It is, of course, much easier to find out the on-bottoming by the tension meter in shallow water.

d) After the buckets were on sea-floor, the tension changed very slightly at mark A, or increased gradually at mark I in Fig. 17, regardless of the sway of vessel. These phenomena were also frequently recognized at other stations. Accordingly, it may fairly be assumed that they indicate the behavior of the buckets in dredging: for instance, the weight chain was repeatedly on-and off- bottom, the dragging angle of buckets was small and the buckets were cutting into the sediments.

e) The upper line indicates the vertical component of gantry sway, measured by the strain gauge type accelaration sensor (Fig. 17). At this station (St. 72218), the mean frequency of sway was 0.19 Hz and the period was about 5.3 sec. At other stations the frequency was 0.16–0.21 Hz. As Fig. 17, the form of sway was asymmetric with respect to the horizontal axis and also the amplitude was not constant, because of the irregular sea swell and other factors. It was also recognized that the amplitude of sway of vessel had a tendency to decrease during dredging. These phenomena suggest that the cutting of buckets into sediments is similar to anchoring action.

B. Results of bucket tension measurement

Fig. 18 is an example of records by the bucket tension recorder. The records by 1 ton and 500 kg recorders, respectively corresponded at marks A-P in Fig. 18.

4) Summary

The analytical results of recorders at St. 72218 yield a typical example. In view of the above results the following deductions can be drawn from the total analyses of records at surveyed station (Fig. 19).

a) The on- and off-bottoming of sampling tools, such as buckets and grab samplers etc., can be judged by the measurement of wire rope tension on the deck in spite of the swaying of the vessel.

b) The behavior of buckets during dredging could be clarified by the measurement of wire rope tension and it might give valuable guidance in sampling works.

c) The factors affecting the variation of tension are not only the on- and off-bottoming of tools and the weight of wire rope itself, but also the winding speed of wire rope and the vertical movement of deck by sea swell.

d) In order to judge the behavior of sampling tools etc., more accurately it is desirable that the winding speed of wire rope and the movement of deck should be simultaneously

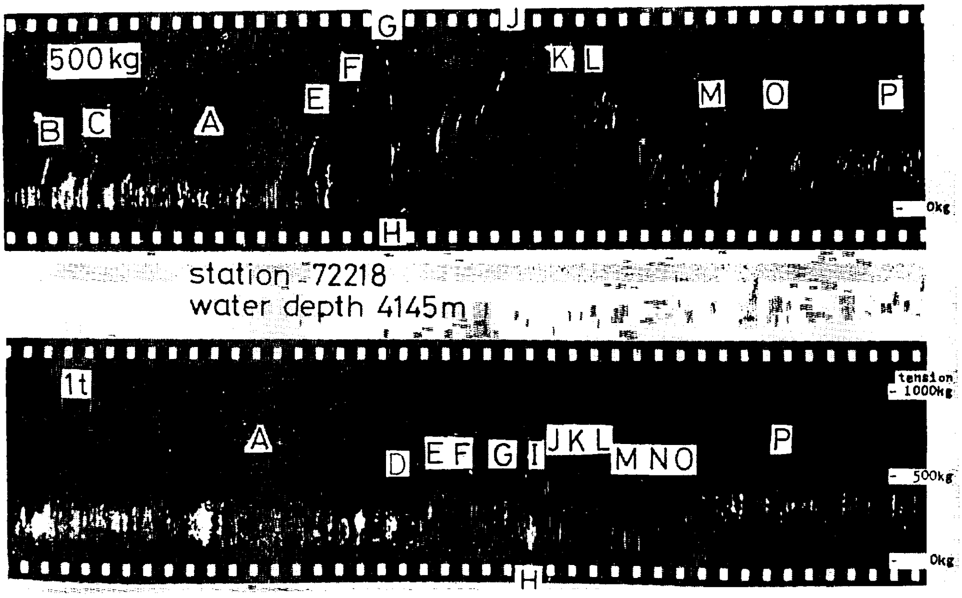

Fig. 18. Records by the bucket tension recorder.

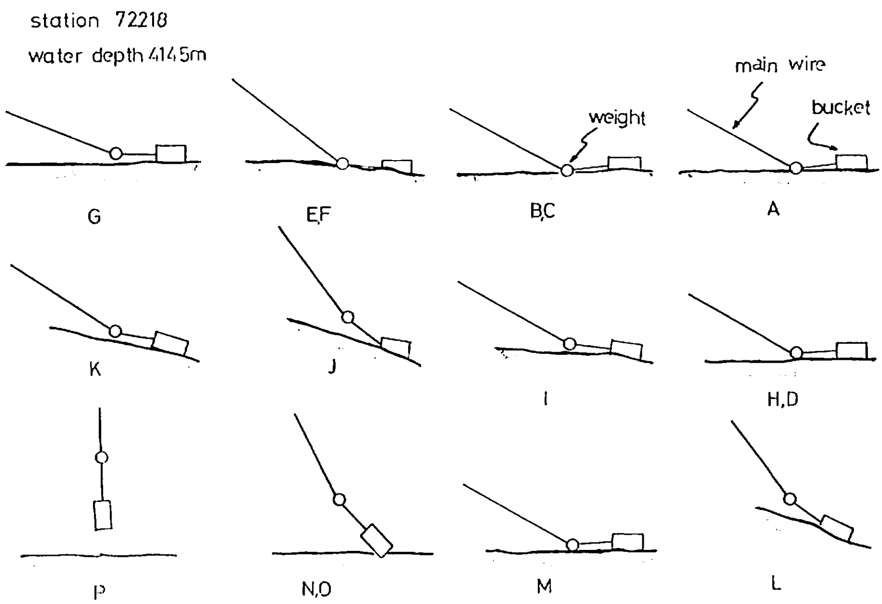

Fig. 19. The behavior of bucket and weight on bottom.

recorded with the measurement of wire tension.

e) The behavior of buckets and weight chain on bottom can easily be inferred by the records of bucket tension recorder. The records are useful for the improvement on the deck and also the improvement of tools and others.

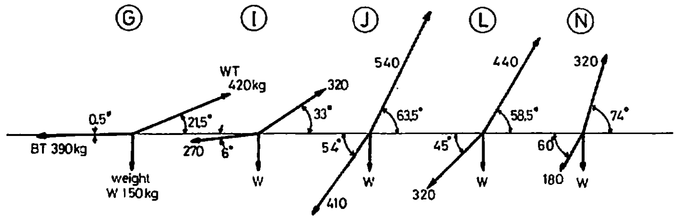

Fig. 20. The vector obtained from WT, BT and weight W.

f) The behavior of buckets and so on are difficult to be clear only by the wire tension records, but can be more easily analyzed by a critical comparison between the wire tension and the bucket tension records (Fig. 20).

5) Considerations

The cylindrical type buckets are very reliable for deep sea sampling. In this cruise, great volumes of soft sediments with ferromanganese nodules were successfully obtained by the buckets at many stations.

Concerning the behavior of buckets in dredging, it can be expected safely that the buckets would cut into the sediments shortly after the start of dragging, because the soft sediments were extremely compacted along the inner wall of open mouth in the buckets. This is in agreement with the test dredging at indoor test tank. Therefore, the dragging time would be saved more for the cylindrical buckets, if the dragging behavior could be judged more precisely. On the other hand, the box type bucket (E-type) can bring favorable results on the abyssal plain where ferromanganese nodules of suitable sizes are distributed. It can be pointed out than the insufficient discharge of soft sediments through the bar screen or net is one of the structural problems, that is, the soft sediments may remain inside the bucket only during dragging. Therefore, better result of sampling could be achieved, if the bucket would be repeatedly on- and off-bottomed for the discharge of soft sediments in water during its dragging.

In view of the above results, it is suggested to have weight difference among buckets and other attachments in order to prevent tangling, and also to grasp the behavior of buckets in more detail. For the latter purpose, the variation of wire rope tension, measured on the deck, was analyzed, and it was possible to be clarify the behavior of buckets at the on- and off-bottoming more accurately on the records. Furthermore, it was evident that the synthetic studies including the bucket tension records and the rolling factor of vessel could bring very important ideas on the behavior of buckets in dredging. The influence of rope angle and real wave height should be the subject of further research for the total analyses of dredging system.

I.3.4 Photographs by deep sea camera

For the photographs at the sea floor, the camera and strobe started to operate when the weight of the bottoming switch struck on the floor, after that the operation was automatically continued at successive intervals of 10 sec. As described already, the sonar pinger was attached on the frame of the deep sea camera, and the interval of sound from the pinger was adjusted to change from 4 to 1 sec., when the weight of bottoming switch hit to the floor. Therefore, the on-bottoming of camera could be recognized by the wire length meter and the change of sound transmitted to the reciever on the deck. The variation of wire tension was also useful for the recognition.

In the cruise the satisfactory photographs were taken at St. 72211 (Figs. 21 ~ 24), but no pictures at St. 72203 because of battery accident.

Fig. 21. Rock exposure and boulders on the sea bottom at station 72211.

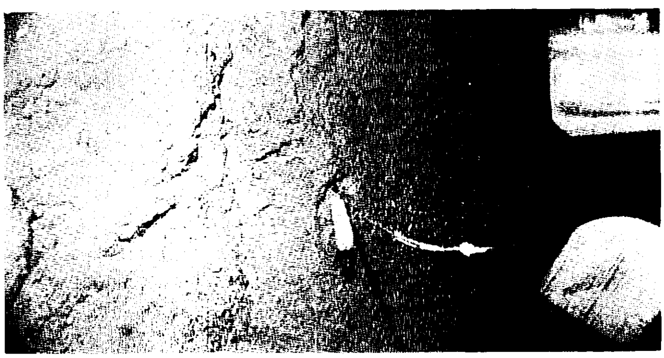

Fig. 22. Rock exposure stepping down to right.

Fig. 23. Unsticking of the weight of bottoming switch, Scattered dark paterns indicate that rock lies beneath very thin deposit of calcareous ooze.

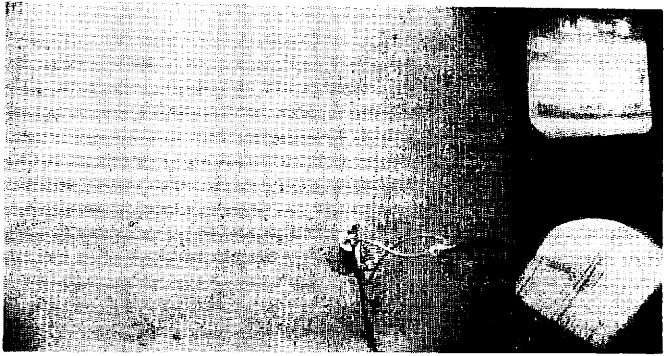

Fig. 24. Thicker deposits of calcareous ooze and ripple-like textures on the surface of sediment.