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Safe And Efficient Operation of Multi Channel Seismic Survey System

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ABSTRACT

Since 1997, Nippon Marine Enterprises Ltd. (NME) has been commissioned from JAMSTEC (Japan Agency for Marine-earth Science and Technology) to operate the Multi Channel Seismic(MSC) survey system (MCS) and Ocean Bottom Seismograph (OBS) amounting more than 100 units. Multi-channel seismic survey system and OBS detect the seismic waves that are artificially made by Airguns installed on towing system of two arrays (starboard side and port side). Each array has 4-airgun units assembled on two towing frames. Totally 8 airguns are mounted in R/V KAIREI.

This paper explains a method of better safety operation by making parallel air supply lines, a method of more efficient operation by fitting stop valves for lines to each airgun, and new type of towing frame system.

KEY WORDS: MCS (Multi Channel Seismic survey system); Safe and efficient operation; stop valve; On-Off valve; air leakage; impact load; cyclic load; new type of towing frame;

INTRODUCTION

R/V KAIREI is not an exclusive vessel only for multi-channel seismic survey system operation. She was designed as a support vessel for full depth ROV KAIKO and also as an ocean research vessel. The multi-channel seismic survey system was added later. Thus, the working space for multi-channel seismic survey system and Airgun arrays deployment/recovery operation is narrow compared with the exclusive multi-channel seismic vessel.

We have been operating this system, and various important data has been obtained, but also we have encountered with many troubles. The largest one is air leakage from jumper air hose. In addition, the narrowness of the working space has obliged us to work very close to the fire-chamber of the Airgun whose pressure is not released to 0atm.

This makes us uneasy, and we have been trying to make the pressure of the adjacent fire-chamber to 0 atm. This paper describes how we have coped with air leakage problem, and how we have complied with the recommendation of the safety features.

MULTI-CHANNEL-SEISMIC-SURVEY-SYSTEM

The present multi-channel seismic survey system of R/V KAIREI is shown Fig.1.This system consists of 2 air-gun arrays, a streamer cable, and 2 paravanes. Each airgun array is towed by umbilical cable and connected to the paravane. The paravanes spread out airgun arrays about 100m.

When shooting, airguns release compressed air (13.8MPa) into the water, and this air generates elastic wave. Regularly we shoot 8 airguns at the same timing to obtain the strong sound pressure and at 50m intervals in distance. This wave reflects from sea bottom and boundaries of under seafloor strata. We record the reflected waves by streamer cable. The streamer cable contains many hydrophones and is totally 4,200m long (168ch), and has 16 depth controllers. In contrast with the above mentioned reflection method, the refracted waves by strata are recorded by OBSs for the wide-angle survey. Analyzing these waves, we can understand the crustal structure. Basic specification of the multi-channel seismic survey system is shown in Table. 1.

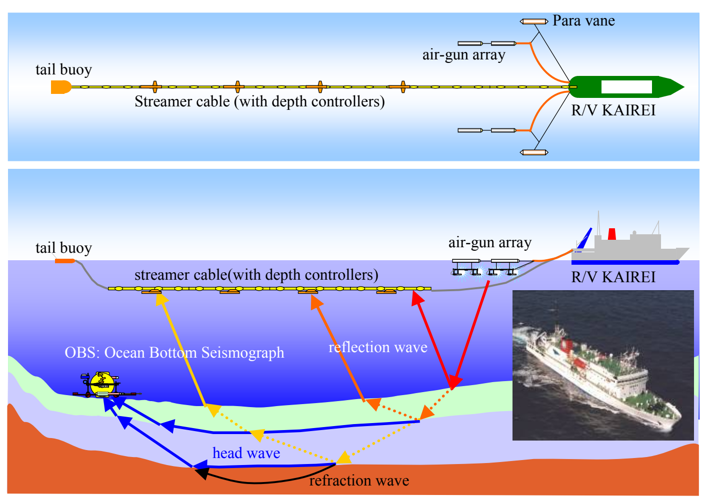

Fig. 1 The present multi-channel seismic survey system of R/VKAIREI

Table.1 Specification of the multi-channel seismic survey system

name	description
air-gun	type : Bolt technology corp. 1500LL volume :0.2m³ (each air-gun 0.025m³) pressure : 13.8MPa depth : 10m
streamer cable	length : 4,200m channel number :168ch depth : 15m (attached 16 depth controllers)
recording instrument	sample rate : 4ms recording length : 15s
umbilical cable	length : ϕ 66mm×140m B.L : 130kN

Table.2 Present airgun arrays towing system specification

name	description
towing frame	ϕ 141mm O.D, Φ122mm I.D 4.6m long stainless steel pipe
float	ϕ 610mm × 5.5m high-density polyethylene
depth-maintaining-rope	ϕ 20mm × 5.5m nylon 3 strands
bundle	ϕ 60mm × 20m air-gun cables and air hose covered by vinyl hose
lifting chain	ϕ 12.5mm × 9.7m Steel
air hose jumper	3/8inch I.D ×2m
fire line jumper cable	pressure sensor line solenoid valve fire line
towing wire	ϕ 14mm stainless steel

PERSENT AIRGUN ARRAYS TOWING SYSTEM

The present airgun arrays towing system is shown in Fig. 2, and its specification is shown in Table.2. One airgun array has two airguns and each airgun is lifted by two struts. These struts allow the airgun to swing back and forth to reduce the impact load. However, this swing motion gives the cyclic bending load to the root of the air hose jumper, and shall damage the jumper hose.

While the airgun arrays are in deployment or recovery, they are suspended by lifting chains and lifting ropes through the floats, but during the survey, the airgun array is suspended by 2 damper ropes. This rope is three strands nylon rope, and keeps the depth of airguns at 10m deep from the surface.

All these 8 airguns are the same type (BOLT Technology Crop), and the volume of the main chamber is bigger than those ordinary used at oil exploration because we are surveying much deeper crustal structures than those by the oil exploration.

The airgun arrays are towed by umbilical cables and towing wires. The umbilical cable has an air-hose in the center of the cable and has several electric lines around the air-hose. Tension member of the umbilical cable is Kevlar, and its breaking strength is 130kN. The airgun array and the termination housing (aft end of the umbilical cable) are connected by a towing rope and a "Bundle" which contains air-hose and electric signal/power lines. This bundle is covered by a vinyl hose as a sheath. The bundle is hanged on the towing wire rope, in order not to be tensioned.

Present towing frame uses stainless-steel pipe as a main beam. Air hose and cables go through this pipe. Each electric line goes directly to the airgun, and the air-hose is branched off from the main air-hose to each airgun at a junction box.

Hydrophone is fitted on center of the towing frame, in order to monitor the shooting condition of the airguns. If air leakage happens, wave data from the monitor hydrophone becomes irregular, and we can recognize the air leakage. Each airgun has solenoid valve as a trigger of the gun and at the same time as a pressure sensor. We can monitor all airguns shooting by this sensor.

Position of the airgun array is determined by R-GPS (referential GPS) system, and GPS antenna is attached on the rear end of the float.

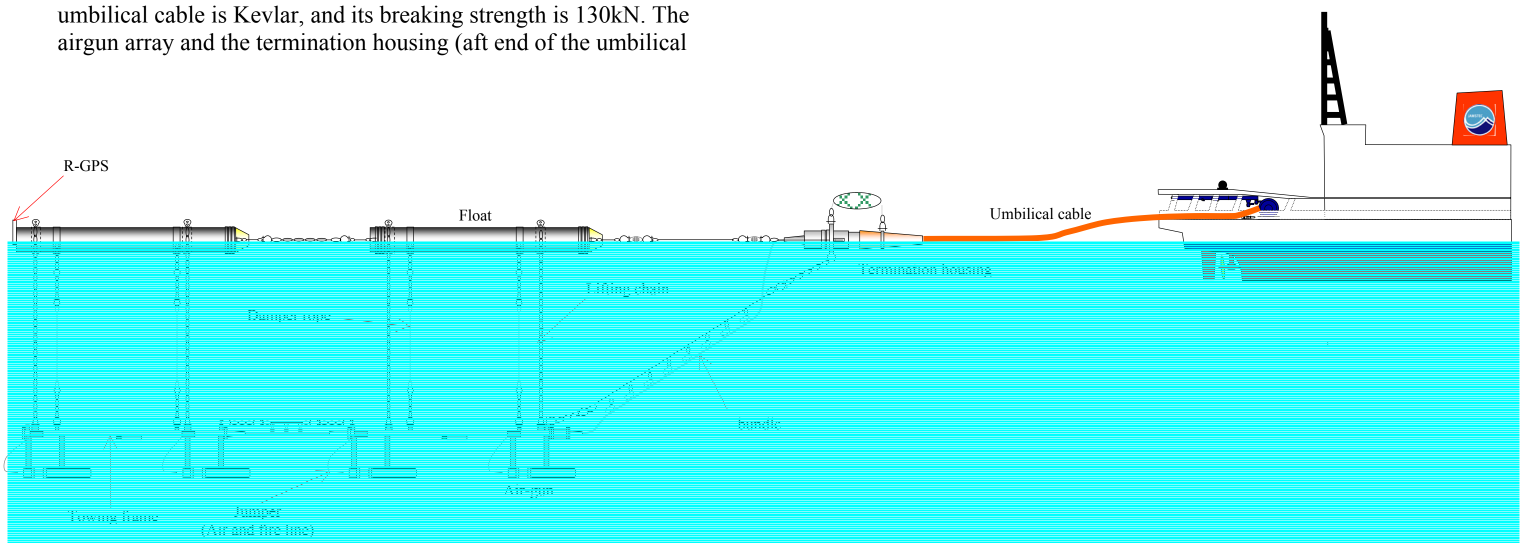

Fig.2 Present airgun arrays towing system

PERSENT LAUNCH/RECOVERY OPERATION OF THE AIRGUN ARRAYS AND THE POINTS TO BE MODIFIED

(1)Working Place close to the Pressurized Airguns

When R/V KAIREI arrives at the survey line, we start the launching operation of the airgun arrays into sea. There are aft and fore airgun arrays at each port/starboard side, and the aft array is launched at first and then the fore array is launched next because of the restriction of the working space. The air hose is common on both aft and fore arrays, and the launched airgun has to be pressurized by about 3MPa in order to prevent seawater enter into the inside of the airguns.

This situation makes the fore airgun array on the deck to be also pressurized. We have to still work on the deck not to entangle the bundle with array or lifting chain. Thus, we have to work close to the airguns filled with high-pressure air. This is shown in Fig.3. Airgun manufacturer's recommendation is to keep the distance by 50ft from the pressurized airgun, but this is beyond the present arrangement on the deck.

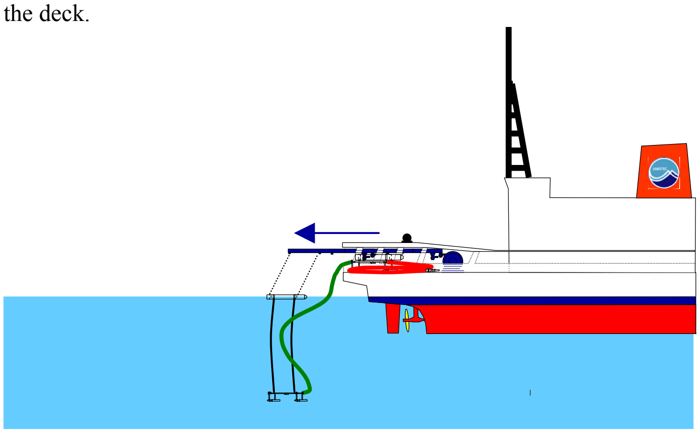

Fig.3 Launching operation of the aft array

After the launching operation of the fore array, we have to work on the deck to launch the bundle slowly not to entangle with array or lifting chain. This situation is shown in Fig.4.

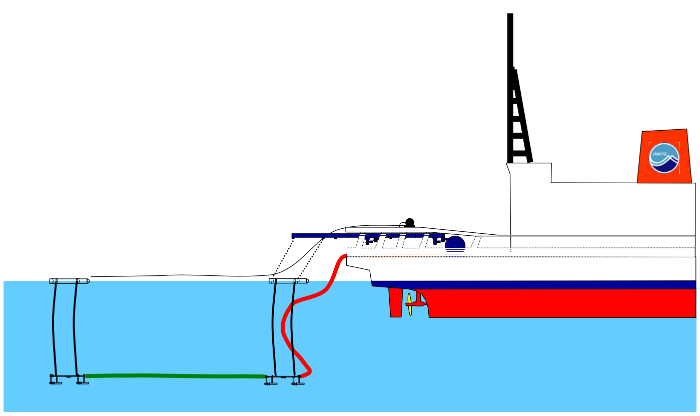

Fig.4 Launching operation of the fore array

After this launching operation, we deploy streamer cable with fitting depth controller at intervals of 150m. It is not unusual to take about half a day to complete this series of operations.

(2)Air Leakage

If a jumper air-hose is broken by impact load or cyclic load given by airguns shooting, the compressed air shall leak from the air hose and the pressure level of airgun drops down. On this situation, we have to recover all the airgun arrays and make up breaking points, and then we must redeploy it.

This recovery and redeploy operations of the airgun arrays require the ship to leave the survey line for the make-up and to re-enter the survey line at the detached point to continue the survey. This turn-around operation consumes usually several hours to half day of the ship time. It is very much preferable to install a system to kill the air leakage line only, and to continue the survey cruise.

(3)Wear of Damper Rope with Lifting Chain

Each array has two lifting chains and two damper ropes, and the forward damper rope is located a little behind the forward lifting chain. This arrangement has not been modified since the introduction of this system to R/V KAIREI, but it has been pointed out many times that the trailing chain shall wear out the damper rope rapidly. This has been really true and we have been urged to modify the arrangement.

(4)Balance of Stress Distribution on the Towing Frame

The lifting chains and damper ropes suspend the towing frame and two heavy airguns. However, the stress distribution on the towing frame is not good, and there is strong bending moment on the center of towing frame (see Fig. 2). This stress has given the frame permanent deformation and also a stress corrosion crack as shown in Fig. 5.

This problem has to be solved as soon as possible. As emergency measures, we already have welded reinforcement plate on the cracking zone, and after we have been using it. But it is not reach a fundamental solution.

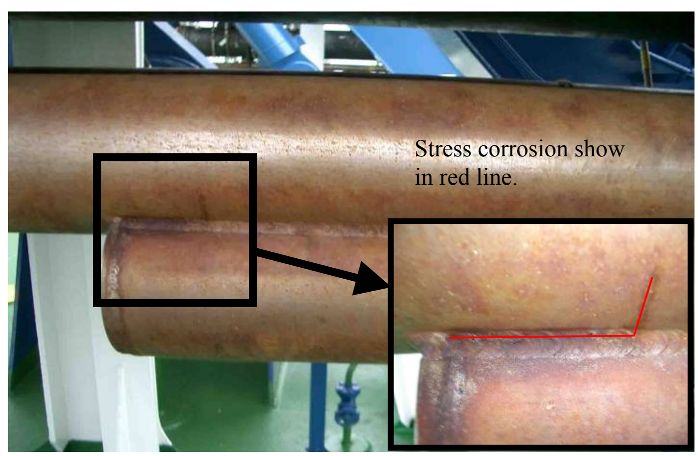

Fig.5 This picture shows the center of towing frame, where the monitor hydrophone container is welded.

IMPROVEMENT OF AIRGUN SYSTEM OPERATION

In order to solve the above-mentioned problems, we started a modification design program. Fig. 6 shows all the design results of the modifications.

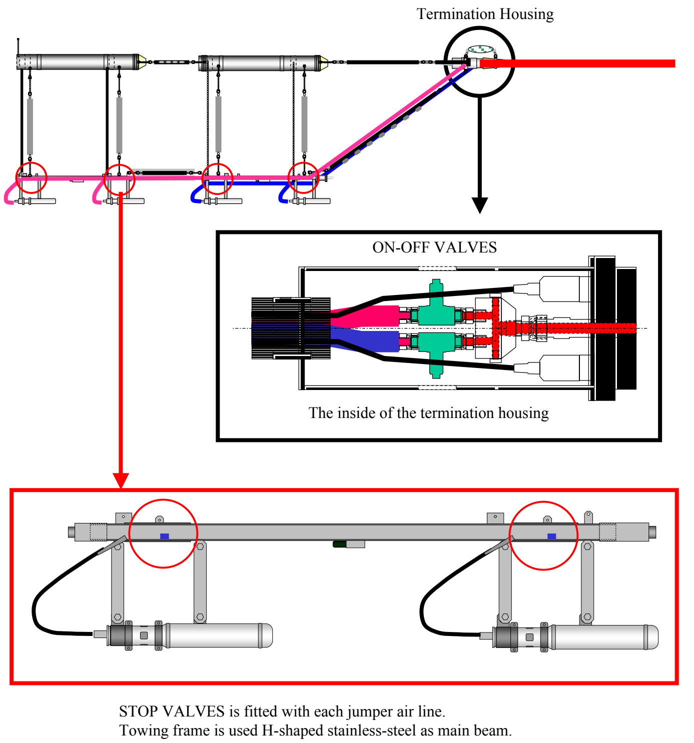

Fig.6 Manually operated On-Off Valves in the Termination Housing, and the Locations of Remotely Operated Stop Valves installed on each branched air hose line to the airgun

(1) Solution to the working problem close to the charged airgun

The main cause of this problem is that we have two airgun towing frames in series arrangement with one common air hose, and the launch/recovery operation has to be done one after one separately. If we can divide the air hose line to each frame, and if we can close each air hose line individually, it becomes a final solution.

The umbilical cable has termination housing at the end, which is connected with bundle. The distance to the closest airgun from this termination housing is about 15m, which is almost fit for the maker's recommendation. So we branched off the common air hose line to two air hose lines, each with manual control valve (ball valve), within this termination housing.

Thus, we can discharge the high-pressure air of the airgun by operating the manual valve about 15m away from the airgun. This modification enables us to work close to the non-charged airgun.

(2) Solution to the Air Leakage

Present airgun system has no valve on branched individual air hoses, and air leakage on any of these branched air hose obliges us to stop survey and request us to recover the airgun system and redeploy it after repair. It is very much preferable if we can kill the damaged branch line. So we introduced stop valve on each branched air hose line. These valves can be operated remotely and individually (see Fig. 7 and Table 3).

This modification enables us to continue the survey even when air leakage happens. We will kill the line at this situation and continue the survey although the airgun power becomes a little weak. When the full power is requested, we will come bake again later to make the survey with perfectly repaired system.

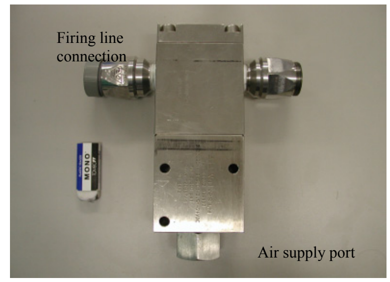

Fig.7 Remotely Operated Stop Valve which can control each airflow

Table.3 Specification of the Remotely Operated Stop Valve and Controller unit (these are made by SEAMAP.CO.)

STOP VALVE	description
Size	18.5×7.5×5 cm
Maximum Working Pressure	2,500psi
Maximum Open Flow Rate	2,500NM ^{3} /hr at 2,500psi
Weight	5.7 kg
CONTROLLER	
No. of Channel	16
Output Power	16 channel at 24 volt, 0.6amp
Input Power	110 to 240 Volt AC,50/60 Hz

(3) Modification of Towing Frame

As mentioned above, the damper rope is always exposed to the wear danger by the lifting chain. This problem can be easily solved by exchanging the their positions. The balance of the stress distribution of the present towing frame is not good and a stress corrosion crack has happened as mentioned above. Further, the remotely operated stop valves cannot be installed on the present towing frame.

So, we renewed the towing frame from pipe structure to the H-shaped beam structure.

The arrangement of the damper rope and the lifting chain has been modified as shown in Fig. 9 where the lifting chain is behind the damper rope. This makes the damper rope free from wear by the lifting chain.

Also the suspending positions of the damper ropes on the towing frame are almost the centers of the airguns each. This makes the maximum bending moment very small as shown in Table 4, and hence, the stress becomes very small.

It is reported that the impact acceleration in vertical direction on the towing frame at airgun shooting amounts to about 10G. The maximum static stress of the present towing frame of the pipe structure is calculated as 22 MPa, and 10G operation shall require 220 MPa strength. The proof stress of the pipe material (SUS304) is 206 MPa, a little smaller than the required strength, although the ultimate strength is above 500 MPa.

The same calculation on H-shaped stainless steel beam showed the maximum static stress to be 6.3 MPa, and it shall become 63 MPa for 10G operations. This is still fairly lower than the proof stress of the material SUS304.

Table.4 Strength Comparison between the present and newly designed towing frame

	present towing frame	new towing frame
shape of cross section	Pipe (SUS304)	H shape-stainless-steel (SUS304)
maximum bending moment	2.5×10^{5} kgmm	1.4×10^{5} kgmm
modulus of section	1.2×10^{5} mm ^{3}	2.2×10^{5} mm ^{3}
second moment of area	8.5×10^{6} mm ^{4}	1.6×10^{7} mm ^{4}
maximum stress	2.2kg/mm ^{2}	0.64kg/mm ^{2}
safe ratio at static load	6.6	23

(4) Additional Modification – Introduction of Swivel Joint

Air leakage often occurs at the connection root of jumper air-hose with the airgun, where impact load and cyclic load are given at every shot of airgun. Thus, the root of jumper air-hose has a danger of fatigue destruction.

There are two methods to solve this problem: one is to strengthen the rigidity of the connection point and the other is to make the connection point perfectly flexible. We have already introduced the former one, and the results are good in some extent. But we are not satisfied with this result, and we introduced the latter method during the modification of the airgun systems.

This is to use swivel joints (see Fig. 8) on the connection points of the air hose with the airgun (see Fig. 9). This swivel joint will make the connection point free from any rotational stresses by shock load and cyclic load at each shot.

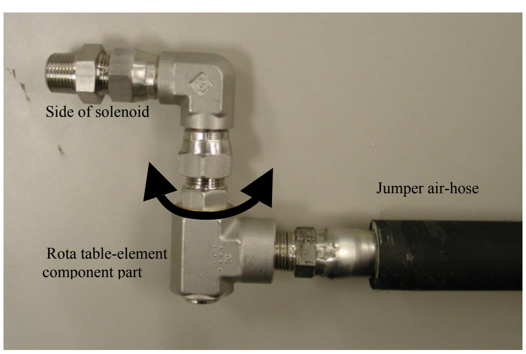

Fig.8 Swivel Joint

It can rotate infinite times around its axis, and it gives the connection point good flexibility.

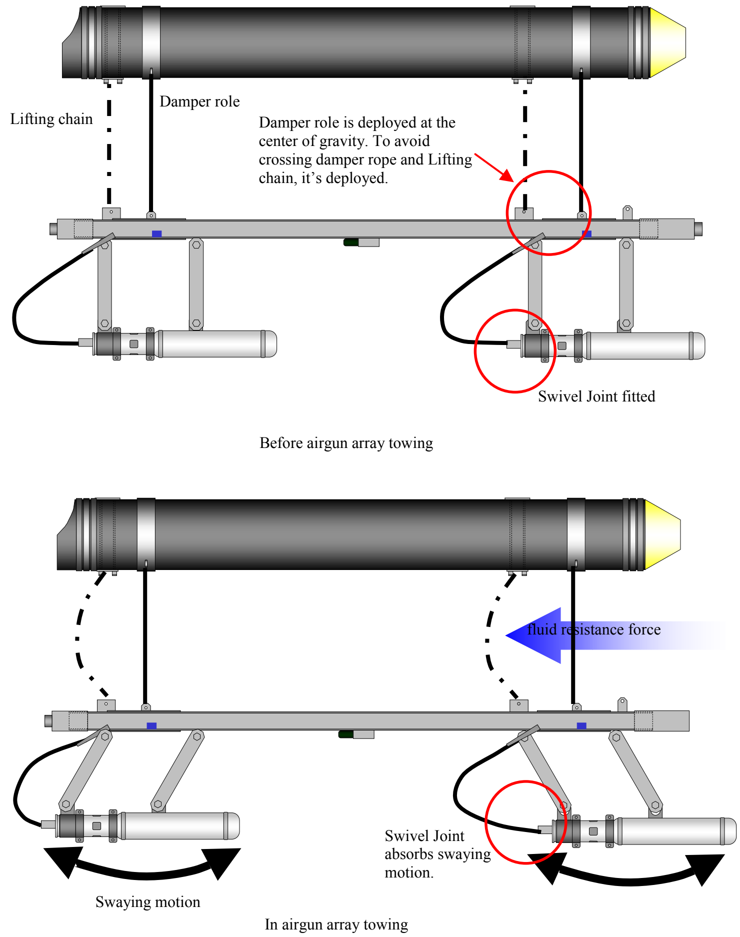

Fig.9 The new type of towing frame that is used H-shape-stainless-steel as main beam, and reducing air leakage unique idea that "Swivel Joint".

(5) Sea Trial Plan

These modifications are now underway and shall be completed on early March 2005, utilizing the dock timing of R/V KAIREI. Soon after then, sea trial of the KAIREI is planned, and Multi-channel seismic survey system /Airgun array towing systems shall also be tested during this sea trial. And after, we have to acknowledge and establish operation manual which air gun array launch/recovery operation, stop valve operation when case to air-leak.

CONCLUSIONS

The ship KAIREI is not a ship dedicated solely for the multi-channel seismic survey. Rather, she is a multi-purpose research vessel mainly designed and constructed as a support vessel for the full ocean depth ROV KAIKO. Thus, there are various inconveniences to operate the multi-channel seismic survey system /Airgun arrays towing system.

However, most marine research institutions may have little energy enough to spare for having a special ship dedicated only for the multi-channel seismic survey system operations. We believe that our struggle and effort to make full use of multi-channel seismic survey system on the multi-purpose research vessel shall become great benefit for the colleague research institutions.

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