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TECHNICAL SYSTEMS USED IN THE ATTEMPTED SALVAGE OF THE ALEXANDER L KIELLAND

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Introduction

In March 1980 the Alexander L Kielland collapsed in the North Sea with the loss of 123 lives. The Pentagon type rig lost one leg and ended up in an inverted position.

The invitation to bid for the salvage of the rig was received in June 1980, the contract was to be completed in approximately twelve weeks, this timescale included diving preparations, software development , system design and structural analysis.

This paper describes the method used in the attempted uprighting and the analyses performed before and during the operation, together with a short outline of the hardware used in the operation.

The basic philosophy adopted for the method of uprighting was to use additional buoyancy and re-distribution of ballast to move the centre of gravity of the rig in such a way that it would adopt a sequence of equilibrium positions leading to the upturned state. The method of additional buoyancy chosen was the use of buoyancy bags to ease installation, to incorporate redundancy into the system and to minimise delays. This method was chosen to minimise the stresses in the structure as all loads imposed on the damaged structure were then well distributed.

Monitoring System

Four sensor boxes were fixed to the rig. Each box contained two inclinometers and two pressure sensors. These sensors were linked to the attitude monitor on the barge adjacent to the rig which consisted of a Texas 9900 microcomputer with 65K of bubble memory. This performed the functions of averaging and numerical differentiation in order to display and store the attitude of the rig and rates of change of the quantities defining this attitude.

A second Texas 9900 was connected (through an A/D interface) to pressure sensors on the air supply manifold and flow meters on the water manifold. This computer performed averaging and display functions and, in the case of the water flow meters, an integration was performed to determine the quantity of water delivered to the tanks on the rig.

A Prime 500 minicomputer together with associated peripherals (80 Mb disc drive, Tektronix,4 V.D.U.'s etc) was also sited on the barge adjacent to the rig. Real-time simulations were performed using this computer to model the behaviour of the rig and determine the stresses in the rig in any given orientation.

The three computers, the ballast monitor and the attitude monitor were all fitted into an air-conditioned container and transported to the site from Southampton in four weeks.

The Simulation Program

On receipt of the invitation to bid for the salvage of the Alexander L Kielland, it was decided that it was essential to determine the rig response and stability characteristics in order to quantify the effects of the operations proposed in the overturning sequence.

The capabilities of the simulation program developed to fulfill these conditions are set out in diagramatic form in Figure 1.

The program was designed on a command-processor basis so that real-time simulations could be performed interactively.

The rig is represented by a number of elements of different types represented by end point coordinates and essential dimensions.

With these elements the component volumes of the rig are defined. The centres of volumes of these elements are also needed for the analysis. The structure associated with these elements gives the mass distribution of the body. Bracing members are defined automatically by end points and connectivity in the usual finite element way.

Additional masses and buoyancy are represented by point masses and buoyancies at their corresponding locations. Because of the irregular shape of the rig, conventional approaches used in ship design could not be easily applied to determine the orientation of the rig and its stability in any position. An approach was developed, which involved the evaluation of the potential energy of the rig and the location of the attitude with minimal potential energy which the rig would naturally assume.

At each ballast state, it is possible to generate data files containing the loads due to the various hydrostatic and gravitational forces on the structure in a form which is immediately useable in a finite-element analysis of the structure. This facility was used in the preparation phase and on site to determine the loads on the structure and the resulting stresses for each ballast condition of the rig.

When the sensors described in section 2 were installed on the rig it then became possible to extend the capabilities of the program in the following ways, associated with real-time monitoring and updating of the program data-base:-

1. The interpretation of the sensor data or actual measurements of the observed rig orientation.

2. The use of the observed orientation in a diagnostic fashion to track down the location of possible leaks or areas of damage when anomolies occur between predictions and observations.

The systems described above enabled the Structural Dynamics Limited team to have full knowledge of the state of the rig during all ballasting operations performed on it.

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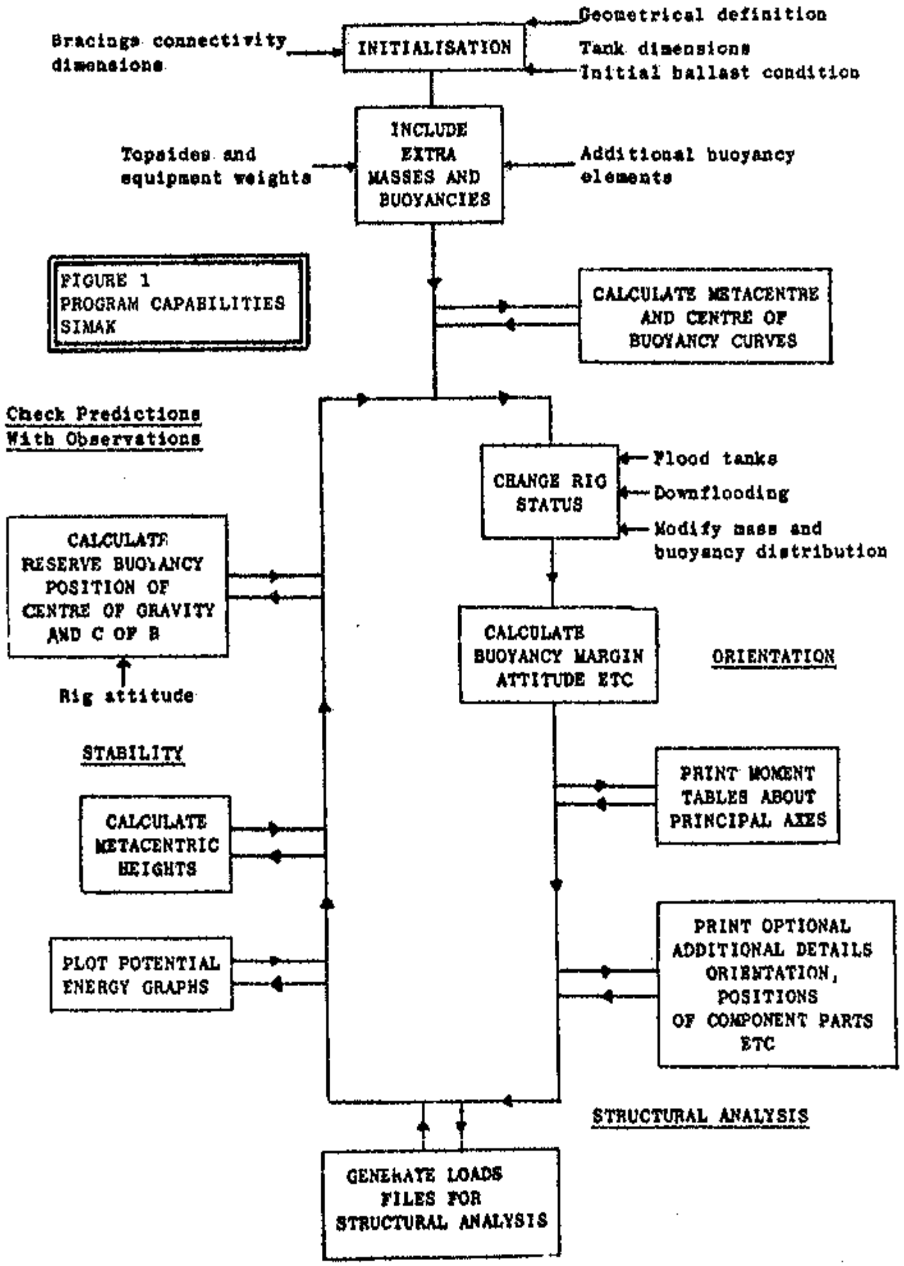

FIGURE 1
PROGRAM CAPABILITIES
SIMAK

VIBRATION OF THIN-WALLED LIQUID-FILLED PIPES

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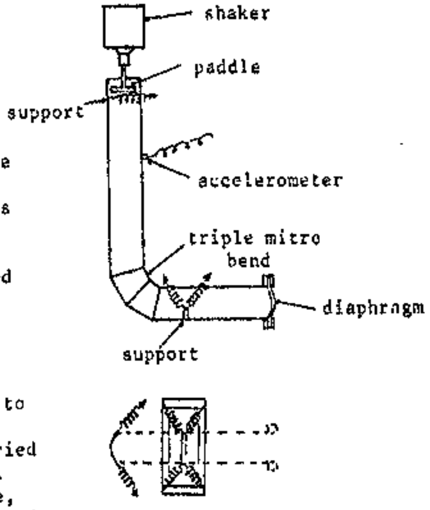
INTRODUCTION An earlier paper, Wilkinson (1978) gave a transfer matrix theory for predicting vibrations of thin-walled liquid-filled pipe systems and some comparisons with experiment on acoustic mode shapes for an L-pipe. This paper describes some further experimental and theoretical work on the L-pipe model.

EXPERIMENT The L-pipe is sketched on the right. It was about 1 m long, 70 mm diameter, 0.9 mm wall thickness stainless steel. It was driven acoustically by a paddle and shaker dipping in the water. A rubber diaphragm at the bottom retained the water and provided a boundary condition.



To get consistent repeatable results several features had to be developed. To support the pipe while permitting it to vibrate various arrangements of polystyrene blocks, foam rubber etc. were tried but stiffness and damping were not small and could vary with time, water spillage, etc. A spring support system was developed having equal stiffness in all 3 directions and 3 rotations low enough to give a vertical resonance of 4Hz and adequate stability. Calculation of the transfer matrix elements for the support as a constraint gave less than 1% deviation from a unit matrix indicating negligible support effects.

The rubber diaphragm was initially thought to give a pressure zero but it was found that its stiffness was not small enough to neglect and a measurement was attempted. Statically a dial gauge was used to give deflection as a function of pressure, varying water height in the vertical pipe. However, comparisons with theory indicated a dynamic value of about 4½ times as much. A dynamic measurement was attempted with an air filled pipe and a shaker powered piston pushing on the centre of the diaphragm. For a known piston mass resonant frequency and peakwidth imply diaphragm stiffness and damping. However, these are also functions of loading and displacement which is basically conical in the piston tests as against spherical under water loading. Analysis of the results and conversion to test values is still in progress. Stiffness problems were removed at one stage by using a rigid tufnol diaphragm but acoustic damping was then so low that peak amplitude could not be measured reliably. The rubber diaphragm was re-fitted but it was also noted that its