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 time-
scale 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 additio-
nal 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 micro-
computer 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.

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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 connecti-
vity 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.

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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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Bracings connectivity dimensions ────→ INITIALISATION

Geometrical definition
Tank dimensions
Initial ballast condition

Topsides and equipment weights ────→ INCLUDE EXTRA MASSES AND BUOYANCIES ←──── Additional buoyancy elements

FIGURE 1
PROGRAM CAPABILITIES
SIMAK

CALCULATE METACENTRE AND CENTRE OF BUOYANCY CURVES

Check Predictions
With Observations

CHANGE RIG STATUS

— Flood tanks
— Downflooding
— Modify mass and buoyancy distribution

CALCULATE RESERVE BUOYANCY POSITION OF CENTRE OF GRAVITY AND C OF B

CALCULATE BUOYANCY MARGIN ATTITUDE ETC

ORIENTATION

Rig attitude

STABILITY

PRINT MOMENT TABLES ABOUT PRINCIPAL AXES

CALCULATE METACENTRIC HEIGHTS

PLOT POTENTIAL ENERGY GRAPHS

PRINT OPTIONAL ADDITIONAL DETAILS ORIENTATION, POSITIONS OF COMPONENT PARTS ETC

STRUCTURAL ANALYSIS

GENERATE LOADS FILES FOR STRUCTURAL ANALYSIS