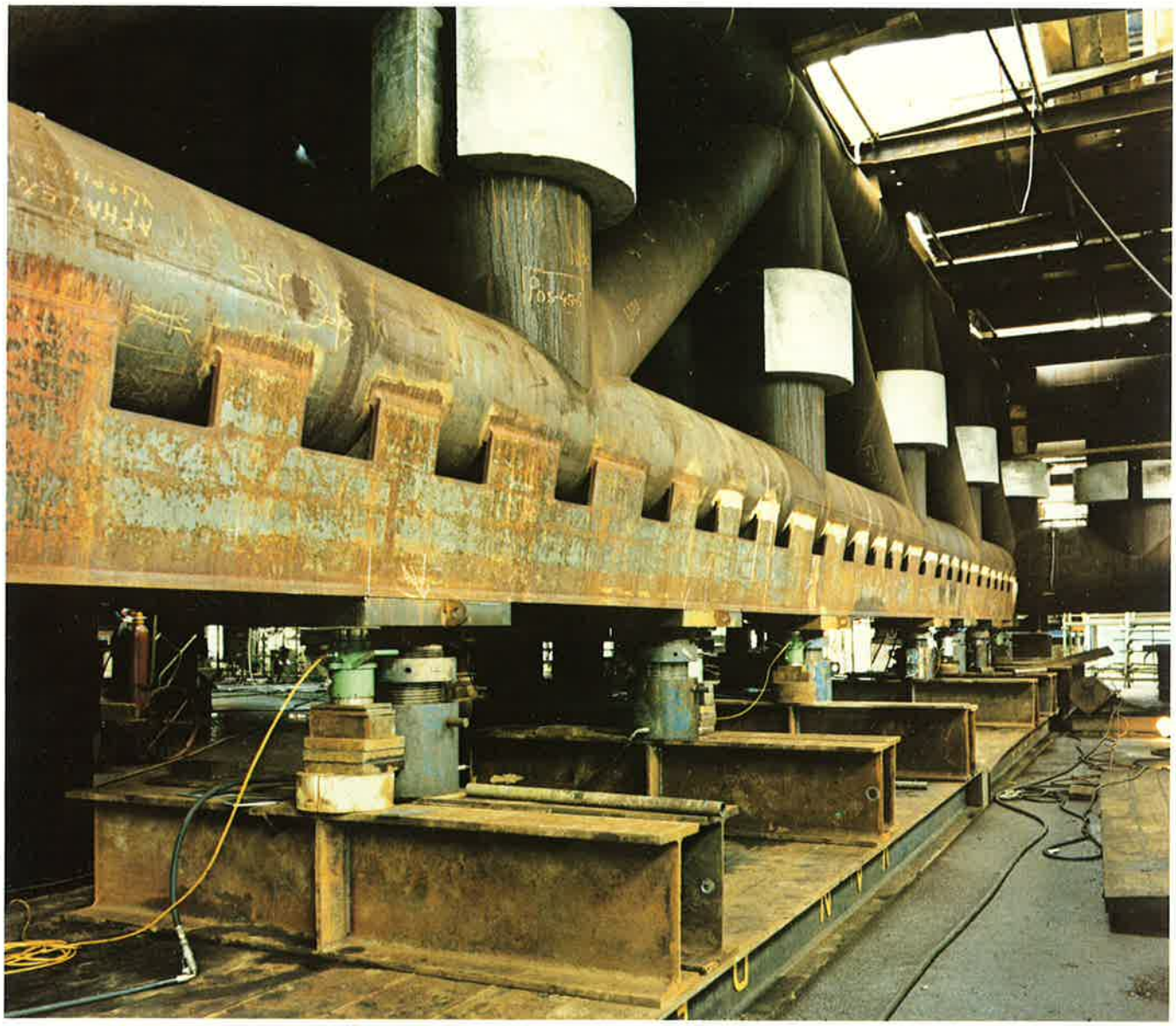
tno-iweco
institute for mechanical constructions

weighing of heavy structures



weighing of heavy structures

measurement of mass
By handling heavy offshore structures during load-out, transportation and installation the accurate figures for mass and for the coordinates of the centre of gravity have to be known in order not to endanger handling.
Many problems and even probably calamities can be prevented when accurate data are available.

TNO-IWECO has the capability and extensive facilities to determine mass and centre of gravity accurately and reliably.
All equipment used, has been certified by well-established certifying authorities.
Great effort is put into obtaining maximum reproducibility within economic limits.
Of every weight assessment, a detailed report is supplied.

Cover photo: *The Shell-Esso Underwater Manifold Centre UMC supported by TNO-IWECO load cells in a weighing procedure.*

Total mass of the UMC (before load out; saddles included): 2117 tons.
Number of load cells used: 16, of which 3 having a 1000 kN and 13 having a 2500 kN nominal range.

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1. *Load out of the UMC.*

2. *With a HP 3054 A data acquisition system, the total mass and the coördinates of the centre of gravity are rapidly computed.*

3. *Barge transport of the UMC (photo Shell).*

4. *16 identical load cells - nominal range 2500 kN - designed and manufactured by TNO-IWECO.*

measuring procedure
The mass of heavy objects is generally determined by load cells which are placed under the relevant structure. The structure is lifted from its supports by hydraulic jacks in order to place the necessary number of load cells into position.
The load cells, still unloaded, but connected to the data aquisition equipment are read out first.
Then, the hydraulic pressure is released and the structure is completely supported by the load cells.

If the load is not sufficiently evenly distributed over the load cells this is corrected by fillings, in order to obtain a more even weight distribution.

In a series of at least four weighings, the data are collected for the ultimate weight assessment, using the hydraulic jacks for the loaded and unloaded condition. The average measured force by each load cell is computer calculated from the measured data of all load/unload conditions.
The calculation also includes processing the calibration data of the load cells concerned. These are stored in the computer memory in a sequence of ten equal intervals in between those intervals the real calibration value is approximated by interpolation.

The total mass and the position of the centre of gravity in the horizontal plane are computed from the load cell outputs and the coördinates of the load cell supports.

5. *Salm project Buoy under construction.*

6. *Buoy; salm project for Shell Expro Ltd. UK. Sum of measured forces 24420 kN with a standard deviation of 63 kN (Photo RDM).*

Total mass, saddles included: 2488 tons
Total mass without saddles: 2209 tons
Centre of gravity:
X-axis: 7998 mm
Y-axis: 25066 mm.
Number of load cells used: 20 of which
15 having a nominal range of 2500 kN and
5 having a nominal range of 1000 kN.


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Accuracy in assessment of weight and centre of gravity position
Accuracy in assessment of weight is not only a matter of certified calibration, not of a precision read out instrument, it is actually very much more.
The various items that can adversely affect the measurement accuracy must be known. So thorough evaluation of both load cells and electronic instrumentation is necessary to get familiar with all possible sources of errors. Some of these errors are of a systematic nature and for such errors proper corrections must be made. All other errors, like the calibration uncertainty, temperature effects on the load cell, pretended accuracy of the electronic indicator, transverse sensitivity of the load cell, must all be considered according to error summation laws.
Highly important in the calculation of the total uncertainty is the repeatability of the assessment as such. From repeated load-unload cycles, mean values of mass and of centre of gravity coordinates must be calculated together with the standard deviation of the measurement series. The standard deviation is a reliable measure for the possible errors, caused by the assessment procedure, including errors due to creep, temperature changes and similar effects.
The totalized error is described as a total uncertainty: a quantity indicating the reliability of the measurement results within stated confidence limits. In the calculation procedure all errors must be differentiated according to origin and type then be adequately totalized.


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In the Institute's weight assessment practice reliable results are produced by offering:
– an adequate weight assessment procedure from experience,
– a justified method of error calculation,
– a certified calibration of the load cells,
– verification of calibrations before and after the weight assessment,
– calculation of total uncertainty in which the standard deviation of repeated measurements is included.

The standardized weight assessment procedure underlines stable and reproducible loading conditions, moreover the measurements are repeated 3,4 or 5 times to obtain maximum statistical reliability.
Load cell calibrations are carried out under the auspices of the British Calibration Service, the Netherlands Calibration Organisation (NKO) or the German Calibration Service (DKD). Calibration uncertainty for load cells up to 500 kN is 0,01% or even lower, for load cells up to 2500 kN the figure is 0,1%.

TNO-IWECO literature: Measurement uncertainty in assessment of weight and centre of gravity position of large (offshore) modules using strain gauge load cells, publication nr. 5015 202-83-1, March 1983

7. *Platform for Cormorant oil field Module UM 4 W.W. for Shell Expro Ltd. UK. (Photo RDM).*
Total mass 706 tons.
Number of load cells used: 4, each having a nominal range of 2500 kN.

8. *Rigid Arm; Salm project for Shell Expro Ltd. UK (Photo RDM).*
Total mass 225 tons.
Number of load cells used: 4, of which 2 having a nominal range of 2500 kN and 2 having a nominal range of 1000 kN..

weighing of heavy structures

owners of objects weighed:
BP
Conoco
Esso
Hoogovens steelworks
Mobil Oil
Shell Expro Ltd.
Rijkswaterstaat
NAM (Nederlandse Aardolie Mij.)

location of weighing action:
Compagnie Francaise d'Entreprise Metallique *(fr)*
De Groot Constructie b.v. *(nl)*
HCG (Hollandse Constructie Groep) *(nl)*
Holland Repair and Services b.v. *(nl)*
Jonker - du Croo n.v. *(nl)*
Kloos n.v. *(nl)*
Nellen kraanbouw b.v. *(nl)*
NSC, Sonderborg *(dk)*
Penn & Bauduin b.v. *(nl)*
RDM (Rotterdamse Droogdok Mij) *(nl)*
Thyssen Nordsee Werke GmbH *(fgr)*
Whitman, New Orleans *(usa)*

transport contractors:
Lastra *(nl)*
Mammoet Shipping/Mammoet Stoof *(nl)*
Sarens, Londerzeel *(b)*
Snellen Vermeer & Partners *(nl)*


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9. *Module HELDER for Union Oil. Total mass 285 tons, measured with 4 load cells, each of them having a nominal range of 2500 kN.*

10. *Base Unit for Mobil Oil. Total mass 957 tons, measured with 7 load cells each of them having a nominal range of 2500 kN.*

11. *NELLEN make Crane on Dock nr. 8 of the RDM yard. Total mass 142,0 tons measured with 4 load cells, each of them having a nominal range of 1000 kN.*


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certification and calibration

certification
Generally used for the mass assessment of heavy structures are the 2500kN load cells which have been designed and manufactured by TNO-IWECO. These load cells have been certified by the British Calibration Service under auspices of which they have been calibrated.

The uncertainty of the mass and c.g. determination is within 0.5% in which temperature effects, transverse sensitivity of the load cells, hysteresis, non-linearity and standard deviation of repeated measurements are included.

The Hewlett-Packard data acquisition equipment has been certified by the Netherlands Calibration Service (NKO). The accuracy of this equipment at nominal load of the load cell is within 0.05%.

re-calibration
Systematic verification of the calibration data of the load cells is an essential condition to obtain an optimal confidence in the measurement results.
The verification is carried out before and after every weighing.

For executing calibrations, TNO-IWECO has a number of facilities available:

machine system	*range*	*steps*	*uncertainty*
dead weight	0–2 kN	20N	$1:10^4$
	0–100 kN	1 kN	$1:10^4$
	0–555 kN	5 kN	$2:10^5$
hydraulic	0–5 MN	cont.	$2:10^3$

As an indicator for Resistance Strain Gauge based load cells under calibration, a laboratory standard with a resolution of $1:10^6$ is available.

12. *Upper Mainframe of the TNO-IWECO 555 kN deadweight standardizing machine.*

about the institute

The IWECO institute is one of the 35 institutes within the Netherlands TNO-Organization for Applied Scientific Research. The Institute has a background expertise of structural mechanics, fluid mechanics, system analysis, control engineering instrumentation and associated disciplines.
The institute actual skills and experience available are related to industrial activities offshore and onshore.
TNO-IWECO employs in total approximate 100 persons of which 45 are university graduates and 25 have a higher national certificate.
The whole TNO-organization, which has it head-office in the Hague, employs some 4700 people of which 900 are qualified scientists and engineers.

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