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WEIGHT CONTROL AT ULSTEIN SHIPYARD, NORWAY

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1 Introduction

1.1 Background

Traditionally weight control has not been a high priority task in Norwegian shipyards. But during the last years more and more contracts have included weight related claims that cannot be ignored. More efficient weight control has been important to meet the new demands.

In 1999 BAS engineering and Ulstein Verft launched a project called "Weight Control During Ship Construction". The project's initial objective was to make the process of obtaining weight information for weight control as effective as possible during the construction of the vessel. To achieve this, establishing procedures to exploit information in existing data models was considered one of the main goals. However, as the project was progressing it turned out that in order to increase the value of the obtained results, a complete weight control procedure had to be made for the shipyard.

1.2 Norwegian shipyards

Norwegian shipyards are small/medium-sized shipyards that are competitive in building advanced and high technology demanding vessels. Resources available for weight control are often very limited and for the personnel involved in weight control only a small fraction of their time are available for weight control activities.

Figure 1: Ulstein Shipyard, Ulsteinvik Norway

1.3 Ulstein Verft

Ulstein Verft is considered one of the most advanced shipyards in Norway. It employs about 600 persons and has yearly turnover of about US$ 100 mill. The shipyard has been very successful, especially in building different types of offshore vessels for the oil offshore industry.

1.4 BAS engineering

BAS engineering has since 1996 been working with weight in the ship- and oil offshore industry. BAS engineering is the developer of ShipWeight, a complete weight-engineering tool for the ship industry. ShipWeight has been employed at Ulstein as the main tool for all weight tasks, and was used in this project.

2 Defining Weight Control

Since weight control previously had been an undefined activity, it was most important to first define the term “Weight Control”. The term “weight” will normally include “weight and centre of gravity” in this paper. “Weight Control” was defined by the three main activities:

- Weight estimation/budgeting (before contract)
- Weight tracking/monitoring (during building)
- Structuring of experienced data (after building)

2.1 Weight estimation/budgeting

“Estimation” was defined to be the term used for the weight estimation before the contract was signed. The current weight estimate at the point of contract signing is defined as the “Estimated weight” and should be used in the weight budget. The deviation between the estimated weight and the weight not to be exceeded to fulfil the contract gives the margin.

2.2 Weight tracking/monitoring

The term “weight tracking” was defined as collecting updated weight information available during building. Such weight estimation can come from new estimations, calculations, 3D product modelling, drawings, vendors and weighing.

“Weight monitoring” is defined as comparing the current weight tracking figures with the budget. The product of weight monitoring is weight reports.

2.3 Structuring of asbuilt data

After the inclining test it is important that the weight database is verified and corrected. The data should be structured so that it can provide a useful basis for estimation of new vessels. One must concentrate on putting each weight items in as specific a weight group as possible to maximize the value of data for reuse.

3 Why is Weight Control Important?

Weight control involves a number of people and it is important that everybody knows the importance of weight control, especially if one has been unfamiliar with the activity. The following points were presented to all involved parties to increase the motivation for weight control activities:

3.1 Avoiding contract claims

Most contracts include paragraphs specifying minimum deadweight requirements. If these requirements are not met, the yard will have claims.

3.2 Fulfilling general vessel specifications

Depending on the vessel type, requirements to speed, strength, stability or seakeeping can be crucial for the vessel's performance. Weight is often the most important parameter for these requirements to be met. In extreme cases, exceeding the expected weight can make the vessel useless.

3.3 Cost control

Weight (especially bulk weight) and cost are two of a kind. Thus, weight control is cost control, and valuable input for accounting and cost estimation.

3.4 Documentation

An increasing number of projects have formal requirements from external parties for the weight documentation. It is also important to be able to document weight changes due to change orders, as this can help avoid unjustifiable claims.

3.5 Input for other operations

Weight control can generate good information to calculations like launching or lifting operations.

3.6 Improve future weight estimations

Most weight estimations at early stages are based upon experience data. It has proved to be very hard to collect good data from earlier projects if no weight control was executed during building.

3.7 Sale and promotion advantages

The significance of documenting good weight control routines to prospective customers is increasing. Weight control also reduces the need of margins, which can be the difference between winning and losing a contract.

4 Status Before Start of Project

The weight activities at Ulstein prior to the project were very much typical of the weight activities at Norwegian shipyards in general. This means that weight control was limited to weight tracking. The collected weight information was accumulated without any other prediction of the final result than the subjective guessing from the one reading the figures. Figure 2 shows graphically the weight control activity.

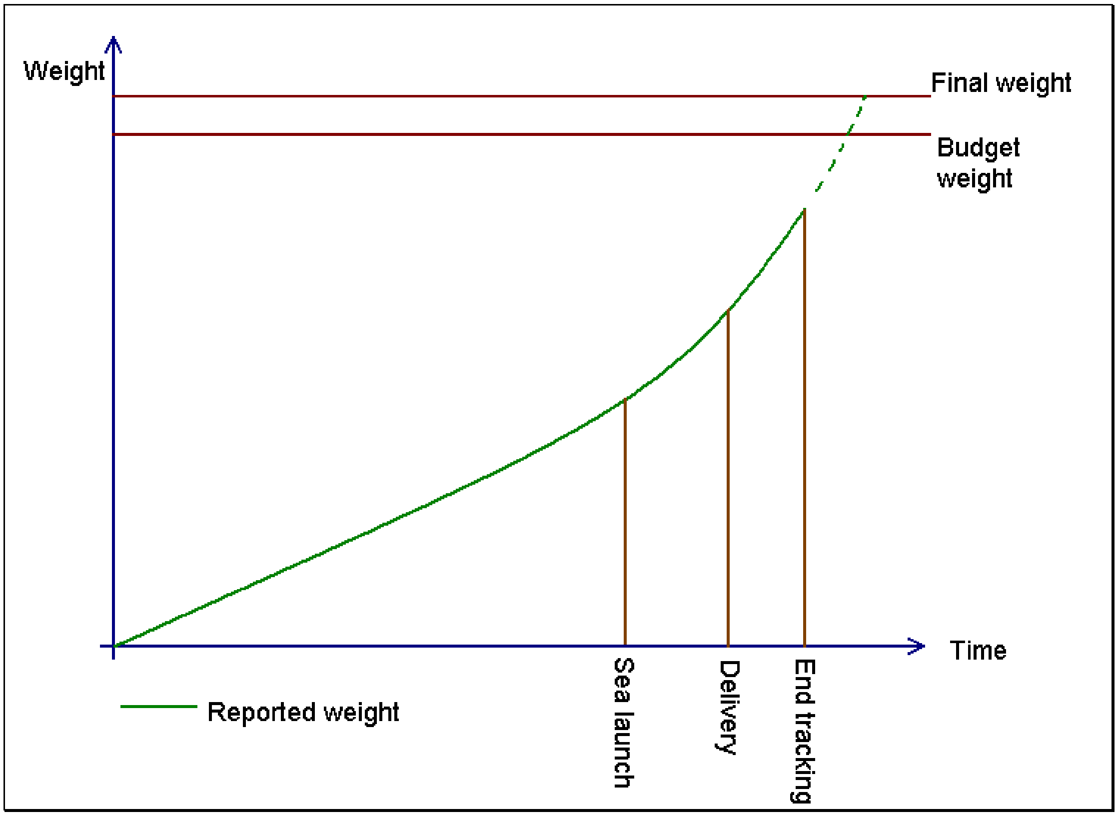


Figure 2: Weight tracking before project

The problems with this approach were numerous: It was very hard to predict whether or not one would keep the weight budget. It could even be unclear what weight should be the budget weight. Moreover, the total weight tracking was not finished at the time of delivery and resources were not set in to finalize the tracking. This made the data unsuitable for reuse in estimation of new vessels. The weight tracking was also constantly lagging behind the real progress so it was hard to make use of the information for operations during the construction.

5 Weight Control Principles

To get a weight control process that solved all the problems that the previous weight tracking represented, some principles were made and focused on by all parties.

5.1 Handling margins

The first term that had to be clear was the use of margins. Margins were defined in many different ways. Depending on who used it or what situation it was used in, it turned out that everything from the welding mass to system liquid could be called margins. This caused a lot of misunderstanding regarding which margins could be exceeded until actions had to be taken.

It was decided that “margins” should mean only one thing: The security factor between the expected weight and the contract weight. In other words, the margin is how much the expected weight can be increased without consequences.

When adding expected, but undefined weights, like welding mass on the steel weight of a CAD model, it should be called “remainder” and not “margin”.

5.2 The principle of 50/50 estimation

Following the principle of limiting margins to only concern security and excluding margins from all the part estimations, comes the principle of 50/50 estimation. This principle states that whenever a weight estimate is done, it is the expected value that should be estimated. This means that it should be equal chance for the real weight to turn out less, as it should be that it turns out more than the estimated value.

If you apply this principle on all estimations, it will ensure that the total estimated value clearly represents the expected value, and any margins added is security with regards to the contract weight.

5.3 The principle of 100% reporting

Previously weight tracking meant that the person responsible for weight on each discipline reported all installed items and only this. Following, it was very hard for the person responsible for the total weight to predict if the final weight would turn out within the margins of the expected weight.

Due to this it was decided that each discipline should not only report the installed weight items, they should also predict the final weight on their discipline each time weight was reported. In other words, the report should contain 100% of the expected weight for that discipline.

It is much better to report an insecure value representing 100% of the discipline weight, than a secure fraction of the total weight. This is because the value of a secure fraction most likely will not be up to date and much less useful in weight control.

There was a lot of scepticism to this approach, but it turned out to be very successful. The disciplines were quite able to make good predictions on the remaining weight. Then it was no longer a problem to compare the total reported weight against the budget weight.

Figure 3 shows graphically how the new approach to weight monitoring gave more weight control.

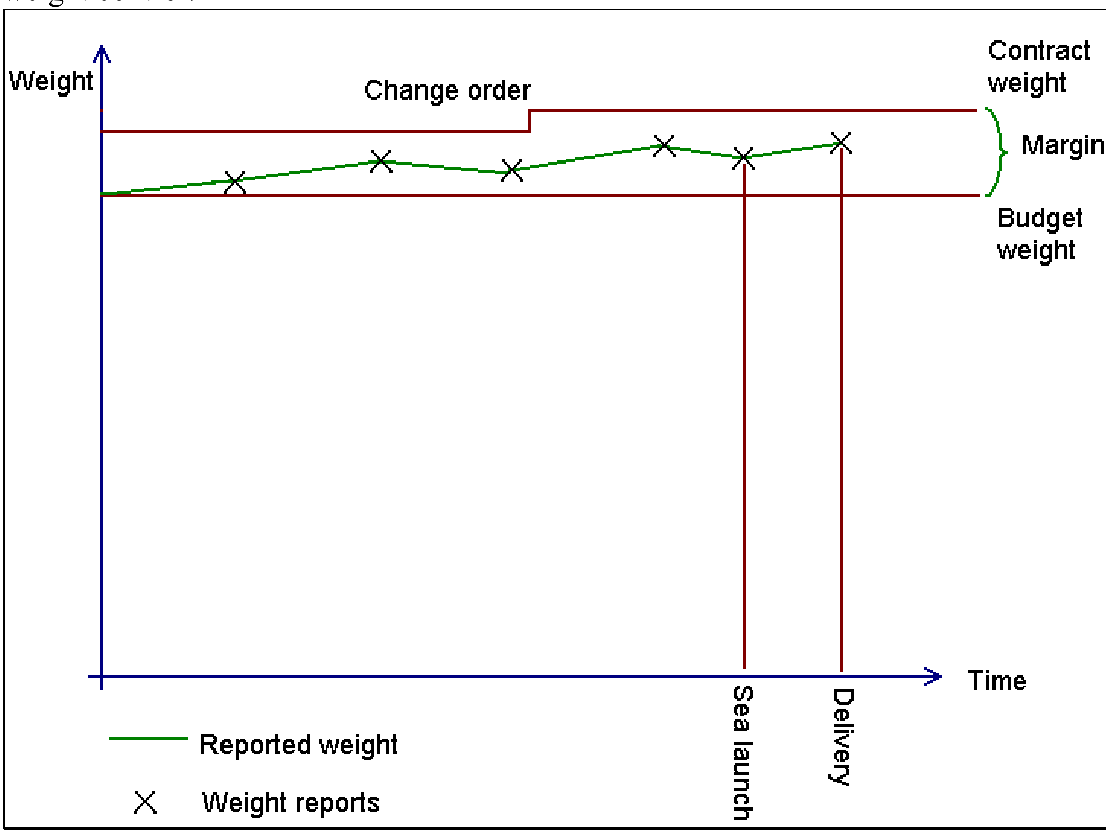


Figure 3: Weight control graph

6 Weight Control Procedures

6.1 Establishing weight budget

It is important to establish a weight budget that the weight control is run against. This weight budget must be in compliance with the contract weight, or, if no contract weight is specifically given, a weight that will make the vessel fulfil contract requirements to deadweight, stability and other performance parameters depending on the weight.

6.2 Organizing the weight control

When the principles for reporting were set, the next step was to organize the weight control in the yard. It was decided to have one person from each discipline be responsible for reporting weight information from that specific discipline.

All reports from the different disciplines should be given to one person chosen to be responsible for the total weight control. It was also decided that this person should be the only one to operate ShipWeight. The disciplines should deliver the weight reports in formats to be imported into ShipWeight; they should not enter it in ShipWeight directly. This was found the most secure way to keep the total weight database as free from errors as possible. Also training costs are reduced, since most people know how to operate spreadsheets.

Obtaining the weight within the disciplines can be done from weighing, vendor information, drawings and 3D product models.

6.3 Weight information from 3D systems

The unexplored and new weight sources in this project were the 3D product models. Over the last years, several 3D model systems had been employed on the yard. These systems had capabilities of handling weight properties for the models, but this had not been exploited.

The only practical way of exploiting weight information in the 3D models within the resources of this project was by exporting an ASCII file from the 3D system, which in turn could be imported to ShipWeight.

The capability of the 3D systems to export in files to be imported into ShipWeight varied very much. But most 3D systems today have integrated some kind of scripting/macro language and within reasonable efforts such scripts/macros can be made to extract the weight information into an ASCII format that can be handled by the weight control system.

ShipConstructor Pro, NAPA Steel, NUPAS/Cadmatics, Tribon and Foran are examples of 3D systems where weight information can be extracted through scripting/macros. The example below shows a script from Tribon using Python programming language to extract weight information.

```
import kcs_util
import kcs_ui
import kcs_dex

project = kcs_util.TB_environment_get(“SB_PROJ_STRUC”)
struct = kcs_ui.string_req(“Structure name”)

if struct[0] == kcs_util.ok():
  com = “STRUCT(‘” + project + “’).ITEM(‘” + struct[1] + “’).”
  ngroup = -1 #impossible number of groups
  if kcs_dex.extract(com + ”NGROUP”) == 0:
    if kcs_dex.next_result() == 1: # integer result type
      ngroup = kcs_dex.get_int() # OK, now ngroup is valid

  if ngroup > 0:
    weight, comp_name = [], []
    total_pos, total_weight = 0, 0.0

    for group in range(1, ngroup+1):
      com2 = com + “GROUP(“ + str(group) + “).”
      npart ) -1 # impossible number of parts
      if kcs_dex.next_result() == 1: # integer result type
        npart = kcs_dex.get_int() # OK, now npart is valid
        total_pos = total_pos + npart
      if npart > 0:
        com3 = com2 + “PART(1:” + str(npart) + “).”
      if kcs_dex.extract(com3 + “WEIGHT”) == 0:
        while kcs_dex.next_result() == 2: # real result type
          w = kcs_dex.get_real()
          total_weight = total_weight + w
          weight.append(w)
      if kcs_dex.extract(com3 + “COMP_NAME”) == 0:
        while kcs_dex.next_result() == 3: # string result type
          comp_name.append(dex.get_string())

print “Structure”, struct[1]
print “ No.       Comp.name          Weight”
print “-----------------------------------“
for I in range(len(comp_name)):
  print “%4d%20s      %8.2f” % (i+1, comp_name[i], weight[i])
print “-----------------------------------“
print “%4d%20s      %8.2f” % (total_pos, “”, total_weight)
```

Figure 4: Scripting/macro example

The exports from 3D systems were tailored so that import into ShipWeight could be done through dialogs in ShipWeight.

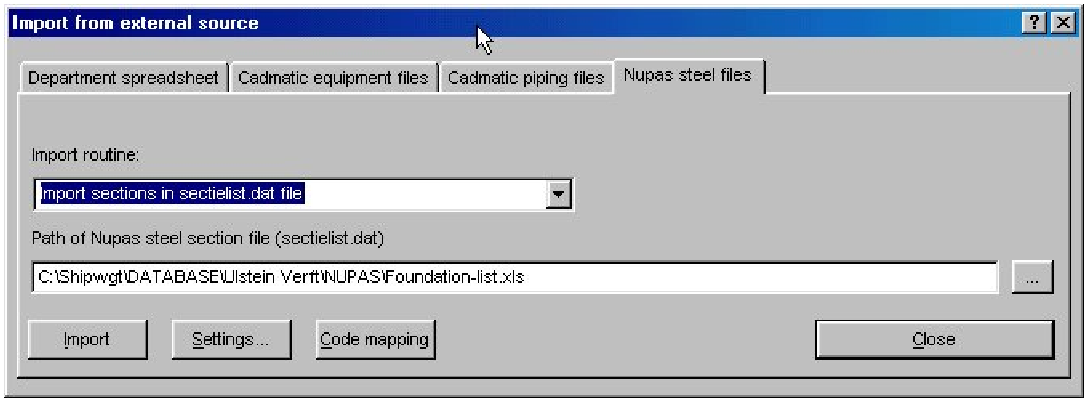
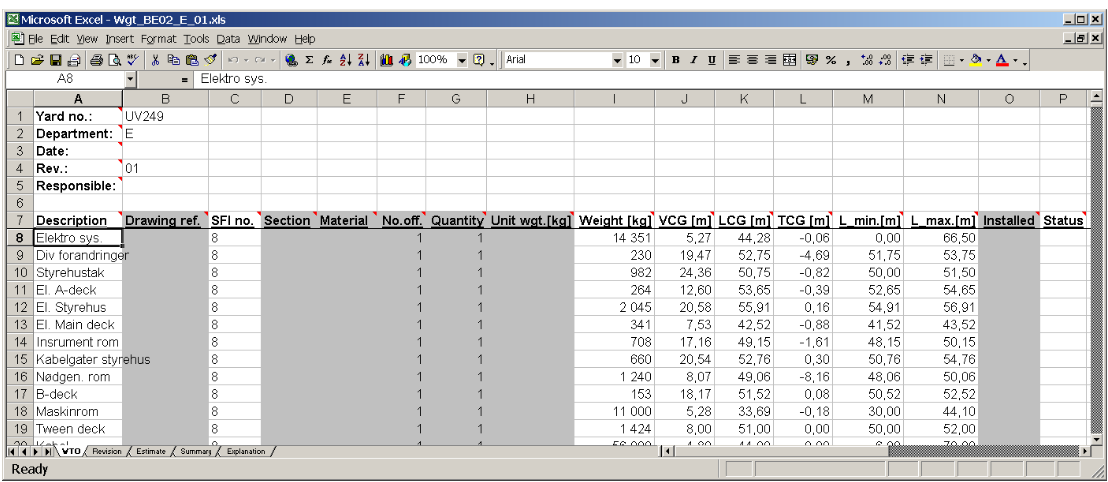


Figure 5: 3D system import dialog in ShipWeight

6.4 Weight information from other sources

It was discussed how weight information that could not be obtained through tailored ASCII files should be reported. As it had been decided that only one person should handle ShipWeight, we found that the discipline contact persons should report all this type of information through standard MS Excel spreadsheets. The spreadsheets should be generated automatically from ShipWeight and distributed to the disciplines. This would ensure a problem-free import to ShipWeight.



Microsoft Excel - Wgt_BE02_E_01.xls

Yard no.:	UV249	
Department:	E	
Date:		
Rev.:	01	
Responsible:		

Description	Drawing ref.	SFI no.	Section	Material	No.off.	Quantity	Unit wgt.[kg]	Weight [kg]	VCG [m]	LCG [m]	TCG [m]	L_min.[m]	L_max.[m]	Installed	Status
Elektro sys.		8			1	1		14 351	5,27	44,28	-0,06	0,00	66,50		
Div forandringer		8			1	1		230	19,47	52,75	-4,69	51,75	53,75		
Styrehustak		8			1	1		982	24,36	50,75	-0,82	50,00	51,50		
El. A-deck		8			1	1		264	12,60	53,65	-0,39	52,65	54,65		
El. Styrehus		8			1	1		2 045	20,58	55,91	0,16	54,91	56,91		
El. Main deck		8			1	1		341	7,53	42,52	-0,88	41,52	43,52		
Insrument rom		8			1	1		708	17,16	49,15	-1,61	48,15	50,15		
Kabelgater styrehus		8			1	1		660	20,54	52,76	0,30	50,76	54,76		
Nødgen. rom		8			1	1		1 240	8,07	49,06	-8,16	48,06	50,06		
B-deck		8			1	1		153	18,17	51,52	0,08	50,52	52,52		
Maskinrom		8			1	1		11 000	5,28	33,69	-0,18	30,00	44,10		
Tween deck		8			1	1		1 424	8,00	51,00	0,00	50,00	52,00		

Figure 6: Spreadsheet for reporting weights from electrical discipline department

6.5 The interval for reports

The intervals for reports may vary from discipline to discipline, but as a starting point one report each month was agreed upon. The reports from the disciplines were then assembled in ShipWeight and a weight report for the total weight was generated. A distribution list of persons to receive the report was also made.

7 The Weight Report

The weight report should provide the following information:

- Summary and conclusion
- Updated weight information
- Trend analyses
- Budget and change order corrections
- Weight information for special operations
- Listing of weights

7.1 Summary and conclusion

The most important information at the summary/conclusion is whether or not the remaining margins are sufficient. This information can be based on the current weight status and results from the trend analyses.

Furthermore, significant deviations between reported weights and the budget weights, as well as deviations between weights in the current report and the previous report, should be pointed out. If possible, these deviations should be explained.

7.2 Updated weight information

The report should include updated weight information on discipline level, and compared with previous reports and budgets, clearly stating the expected weights, budgets and margins. Also corrections as a result of change orders must be specified.

	Revision	**Estimate**	**Rev.01**	**Rev.02**	**Rev.03**	**Rev.04**	**Rev.05**
	Date	4.15.00	5.23.00	6.25.00	7.26.00	8.25.00	9.21.00
a=sym(b1..b2)	LW	1 260	1 125	1 139	1 141	1 216	1 235
b1	2 Hull	900	819	825	825	875	893
b2	3 Equipment for cargo	70	54	62	58	73	70
b3	4 Ship equipment	130	101	100	110	118	119
b4	5 Equipment for crew and passengers	30	32	33	33	33	35
b5	6 Machinery main components	100	95	94	90	90	93
b6	7 Systems for machinery main comp.	20	15	17	16	18	17
b7	8 Ship common systems	10	9	8	9	9	8
	NVC5000 budget:						
c	Contract weight:	1 300	1 300	1 300	1 300	1 300	1 300
d=a	Reported weight:	1 260	1 125	1 139	1 141	1 216	1 235
e=c-d	Margin acc to 1st budget:	40	175	161	159	84	102
f=0.05*700t	1st limit for claim	35	35	35	35	35	35
g	Change order	0	4	11	22	28	37
h=f+g	New limit for claim:	35	39	46	57	63	72
i=c+g	Margin acc to claim:	40	179	172	181	112	138

Figure 7: Weight information on discipline level, including budget and margin data

7.3 Trend analyses

It is very important to predict the final weight based on the weight trends uncovered by the reports during construction. Graphs are very useful for this, and the following graphs were selected in the report:

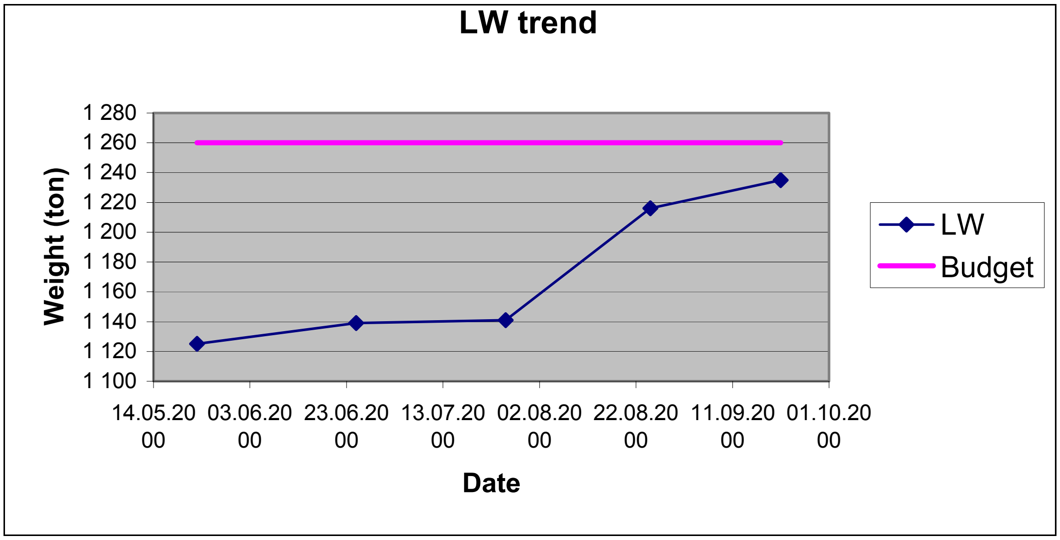


Figure 8: Lightship trend

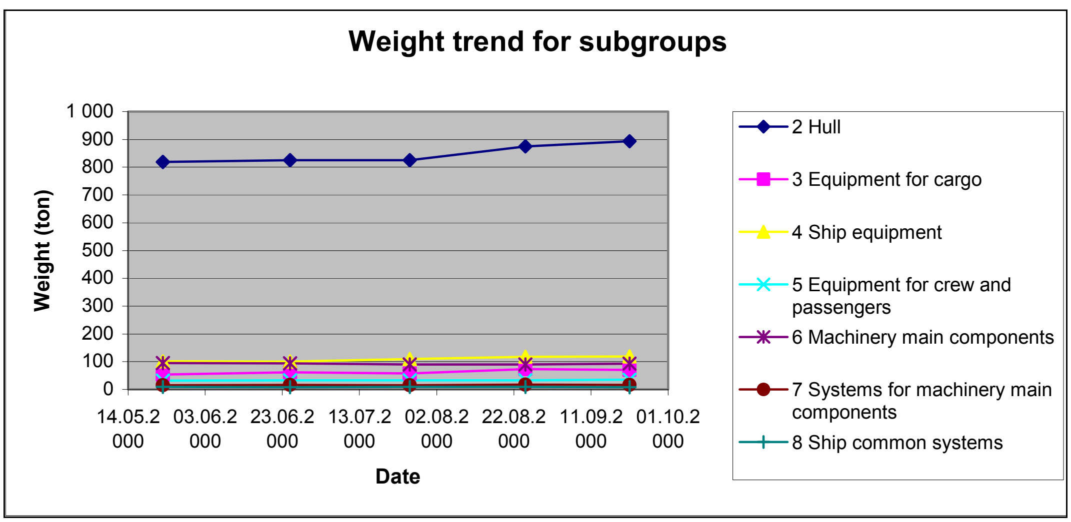


Figure 9: Weight trends for subgroups

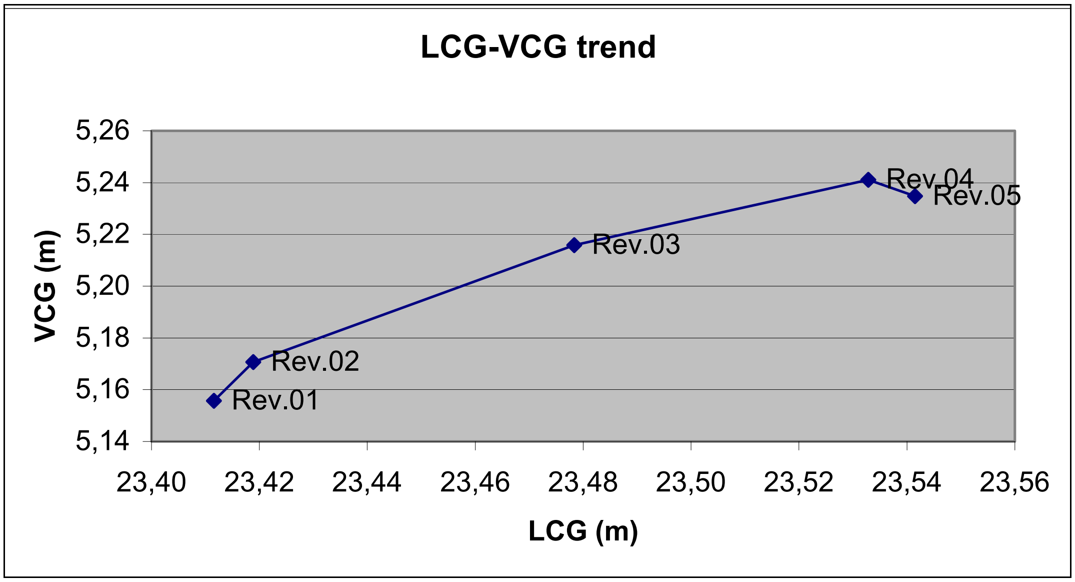


Figure 10: Lcg and vcg trend

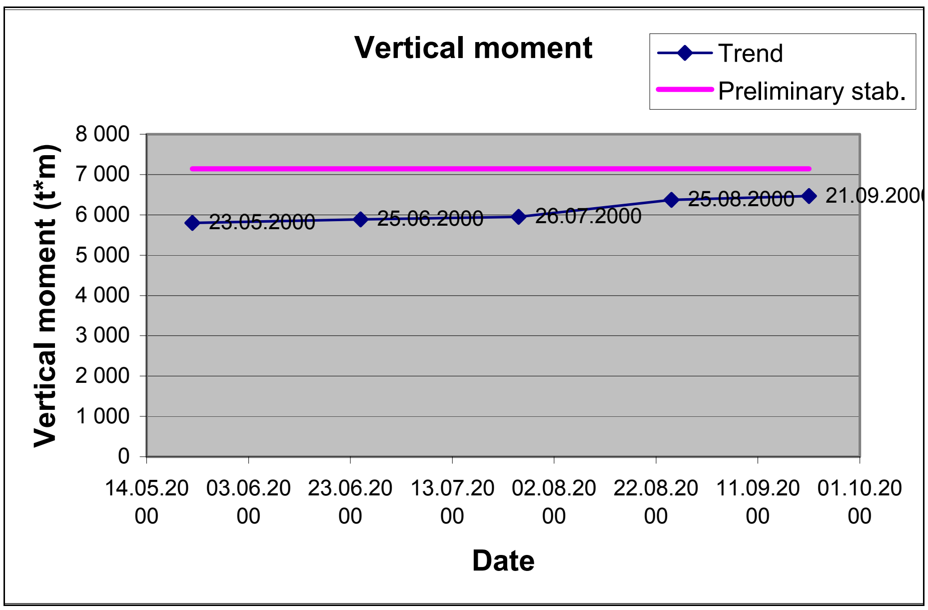


Figure 11: Vertical moment

The vertical moment is the product of lightship weight and vertical center of gravity. It is monitored to ensure that the moment obtained from inclining test values will not exceed the moment used in calculations of preliminary stability.

The graphs might very well also be followed by listings accordingly.

7.4 Budget and change order correction

A chapter in the weight report should clearly state the weight budget and how this is obtained, what contract constraints are current and how change orders influence on this. A list of all the change orders should be presented.

7.5 Weight information for special operations

It is very useful to screen out weight information for operations like launching in a separate chapter to make this information easily available for those in charge of the operations.

7.6 Listing of weights

Detailed listing of the latest updated weights can be appended to the report for examination of special weights and for verifications.

8 Verification of the Weight Database

The reported weights should be verified to secure the reliability of the weight database. Actions to verify the report can be taken by:

- Checking the centre of gravity against area codes and area limits.
- Checking centre of gravity visually by plotting weight items' longitudinal and vertical position against a profile of the vessel.
- Checking the weight listing against the installed components by manual survey on the vessel. Special listings should be generated for this task.
- The final weight report should be checked against the results from the inclining test report.

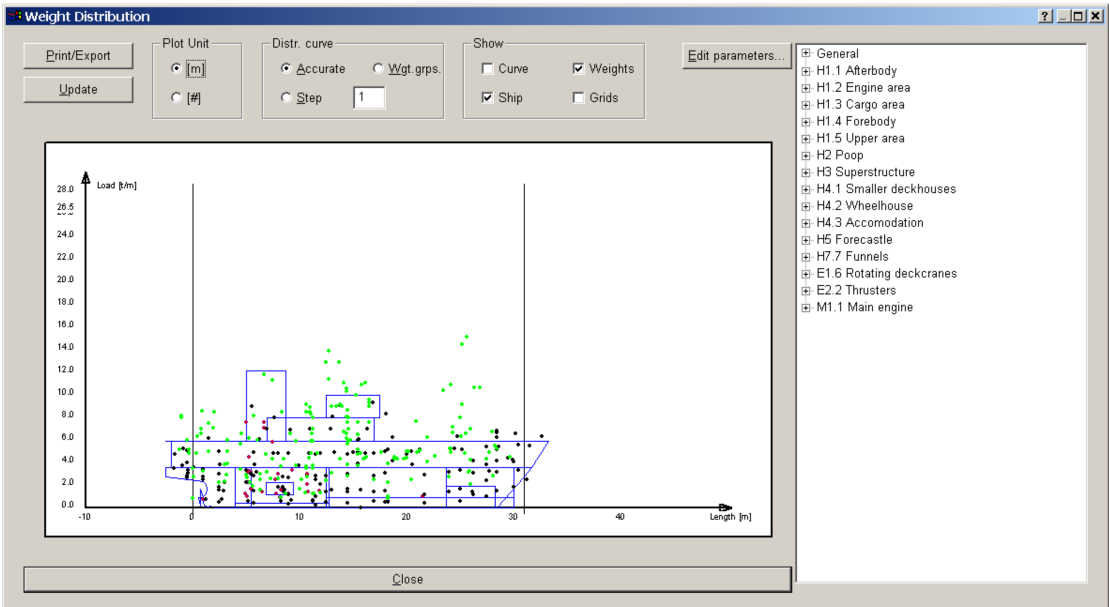


Figure 12: Checking vcg and lcg in the weight database

9 Generating Experience Data from the Weight Tracking

Last, but not least, the final weight information should be prepared for reuse in projects to come. To be able to do this, the weight data must have been structured according to an unambiguous work breakdown structure. To establish scalable experience data it is also important to identify:

- Main parameters
- Capacity numbers
- Physical parameters (volumes, areas)

The degrees of detail for these parameters are dependent on the detail level of the weight information and the parameters that are included in the estimation methods.

10 Summary of Results

The procedures and recommendations of this paper have been executed already to the full extent on two project, and another that is currently under construction.

The results so far have been very good. The project has been deemed successful, and with possible minor adjustments, this will be run as standard weight control on all future constructions at Ulstein shipyard. Especially the results for LCG were improved.

Some of the results obtained are:

- Hours used on weight control have decreased. The standardized reporting format from the different disciplines and the import procedures from 3D systems have decreased the number of hours used on weight control.

- The quality of the weight information is better. The principle of 100% weight reporting gives better control on budgets and contract requirements.

- Faster access to up to date information during construction. The weight information can to a greater extent be used on stability calculations, transportation and production planning. Actions to prevent exceeding the contract weight can be taken at an earlier time.

- Better asbuilt data for estimation of new vessels. The asbuilt information is more complete and reliable and makes new estimations more accurate. This reduces the needs for margins and increases the chances of winning new contract.

Results in figures:

- The four latest vessels build at Ulstein before the new procedures had the following deviation between inclining test and weight database (at time of inclining test):
  - Yard no 224 – 3,4%
  - Yard no 236 – 4,4%
  - Yard no 248 – 2,2%
  - Yard no 251 – 2,5%

- Completed ships after the new procedures have had the following corresponding values:
  - Yard no 252 – 0,15%
  - Yard no 257 – 0,08%
  - Yard no 263 – 0,73%

- The average number of hours used on weight control for a project has gone down from about 650 to about 500 man-hours.