

VOLUME 5

DAMAGE STABILITY

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5.1 Damage stability

5.1.1 General remarks

Damage stability calculation is a subject for continuous increasing need. The activity to protect against pollution has resulted in a number of new IMO regulations.

The Seaking package contains three different programs for damage stability calculations as follows:

- The ordinary damage stability program. This program is the far most used of three programs and therefore called just Damage stability program.
- Subdivision and damage stability in accordance with IMO A265. For passenger ships there are two alternatives for carrying out the calculations. Either using SOLAS74 regulation, which is made by program in the item above or in accordance with IMO A265. This program has been developed to perform the very complicated and extensive calculations required for satisfaction of the IMO A265 regulation.
- Damage stability program calculation the process of flooding in real time. The program in item 1 and 2 are developed with special purpose to cover all IMO regulations. The special program mentioned here is developed with the aim to give the user a possibility to simulate the real flooding procedure under the assumption that the flooding takes some time and the ship heels and trims continuously due to the flooded water.

5.1.2 Damage stability program

Program features

- The program covers all preset IMO regulations except for the “equivalent” for passenger ships, IMO A265 (for which a special Seaking program is available)
- The effect on the GZ curves of liquids in tanks is taken into consideration in exact way. For damaged compartments containing liquids there are the following alternatives for inflow:
 1. Mixing liquid and SW
 2. No mixing. Sea water above or below the liquid depending on densities.
 3. Immediate outflow of the cargo before sea water flooding.
- Options to study stability during flooding, before and after cross flooding. Also the effect of progressive flooding can be studied.
- The program calculates all data for the damaged ship. In addition the minimum intact GM is evaluated. This evaluation is based on stipulated criteria requirements for damaged ship such as max angle of list, minimum freeboard etc.
- For description of damage spaces, a very flexible and general system is available. (The same system is used for all types of capacity calculations in the Seaking package).
- Permeability can be varied inside the compartment both longitudinally, vertically and sideways.
- Flooded water on more decks above each other at the same time can be treated.
- Series of loading conditions can automatically be generated.
- Flexible running procedure and printout. During the investigation phase of the study a shortened printout can be chosen. A complete report is printed at the end of the investigation.
- Stability analysis can be performed for SB or PS heeling or if necessary for both directions. Sometimes heeling to one side is the most critical during flooding and to the other side in the final stage of flooding.

Damage stability is based on data calculated by the following programs in the Seaking package:

1. Hull form
2. Intact stability data (form stability)
3. Compartment data

5.1.3 Description of program and data sheets

The program and calculation procedure will be described together with the data sheets. The calculation is performed for a series of alternative damage cases. Each such damage is described in detail on data sheet dm3. A damage case can be analyzed for one or more conditions for the intact ship. Each intact condition is therefore described in detail (see data sheet dm2).

On data sheet dm4 and dm5 all information necessary for evaluation of the calculated damaged condition regarding applicable IMO regulations are stated.

All calculated results are stored in computer memory and only the requested data are printed during the calculation. When all calculations are finalized a final report of the calculation is printed. Data on sheet dm6 control details in report.

Basic calculation procedure:

DAM1

Program reads data sheets dm1, dm2 and dm3. Input is tested from logical point of view. Loading conditions are completed with draft, trim, displacement, LCG, KG etc. Heeling moment from liquids in tanks is calculated for various angles of heel. Data stored on disc memory in printed if requested.

DAM2

For loading-damage cases stated above, flooded SW, draft, trim, displacement, righting arms etc. are calculated for defined stages of flooding. Calculated data are stored on disc. Result can be printed upon request as intermediate printout.

DAM3

Program reads data sheets dm4 and dm5. Calculated results are analyzed in accordance with the stated criteria requirements. Minimum GM requirements as well as angles of flooding of deck, openings etc. are calculated and stored on disc. Intermediate result is printed upon request. There is also a possibility to get the final result in this stage. The output version prints the result in such a sequence that all results are presented separately for each loading-damage case.

DAM4

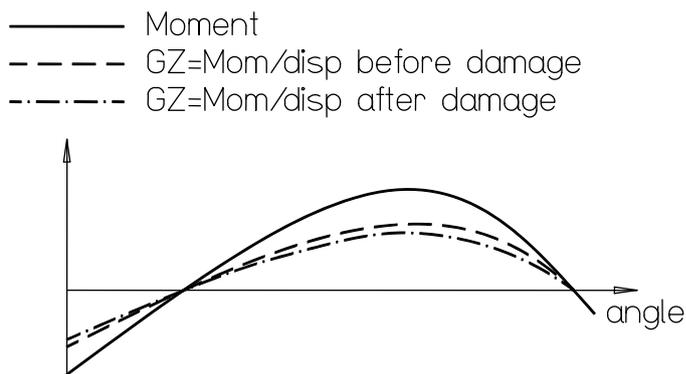
Program reads data sheet dm6 and the final damage stability report is printed.

5.1.4 Description of data sheets

Data sheet dm1

- 11** *ship no* must be the same to the one with hull definition.
i user can split the calculation in any number of steps to analyze results before further calculation.
All results are saved to enable the printing of the final report of all calculations at the end
i =0 clears the memory for the damage stability result
i =1 keeps previous results and the new calculations are added to the memory
spec special version of the program
iprin =0 normally
iprin =1 skip printing the input data
iend =0 terminate if errors are found
iend =1 continues regardless of any errors (if there is a serious error, the program terminates because the calculation would be without any value)
- 12** *fproc* controls the flooding procedures. For details see the description of flooding stage factor for data sheet dm3.

method There are two main methods to perform damage stability calculations normally called the “Lost buoyancy” or the “added weight” method. Only the second method is meaningful if the damaged ship is analyzed during the flooding period. For this reason the program works with the “added weight” method. The calculation of the heeling or righting moment at different angles of heel is straight forward. To obtain the GZ curve, the moment curve has to be divided by displacement. There are two possibilities: either the intact displacement can be used or the displacement including flooded water. These alternatives give the same angle of heel but different GM values and different areas below the GZ curve. Even if it appears most correct to use displacement including flooded water, we find it more reasonable to use the intact displacement. By the factor **method** both alternatives are available.



flooding stage factor is used by program when the corresponding information is omitted for the individual damage cases. See description of flooding stage factor for data sheet dm3.

N.B.

If flooding stage factor is stated in data set **12**, then data set **74**, on data sheet dm3, can be filled just with an “/”.

- 13** **accuracy code** gives a user the possibility to balance computer time against accuracy (for details see appendix 1)
- 14** **print codes** give possibility to print various intermediate results of the calculation. A detail specification on intermediate results given is appendix 2.
- 15** **storage of data** is intended for computer with limited storage capacity and need for storage of selected data only.

Data sheet dm2

61 **loading case number** refers to the intact loading condition

62 **description of the loading case** has four alternatives:

- alt.1; draught and trim
- alt.2; displacement and trim
- alt.3; displacement and longitudinal center of gravity
- alt.4; a series of loading conditions – in this case two numbers have to be stated for load case number in data set **61**

Explanation: If loading case number is 7 21 the program generates 15 loading conditions with numbers 7,8,...,21. The data are linearly interpolated between stated values for ρ , Δ , T etc. In addition, salt water density, centre of gravity from CL (CCG) and BL (KG) are defined. The KG value is, however, optional. If KG is given, it is used in calculation of GZ curves. In spite of this, the maximum intact KG value which meets the specified criteria is calculated. The difference between these two KG values is thus the positive or negative margin in KG. If KG is skipped, the maximum allowable KG fulfilling the criteria is calculated and all curves of damage stability are calculated as if the ship had this intact KG value.

m is the number of loading condition with liquid compartments to be included in the condition. These liquid compartments are called “included data”. Data in data set 64 (if any) are added to included data. If the same compartment is indicated in included data and in data set **64**, the included data is replaced by these new data in data set **64**. By stating the volume =0 for a compartment, the liquid in the included compartment is deleted.

N.B.

If data set **63** and/or **64** is skipped, enter a blank line for each data set.

63 *damage cases to be calculated*

64 compartments with fluid cargo, up to 30, can be specified before damage for each loading condition. There are two cases to consider, as follows:

a) A tank containing fluid cargo is not damaged

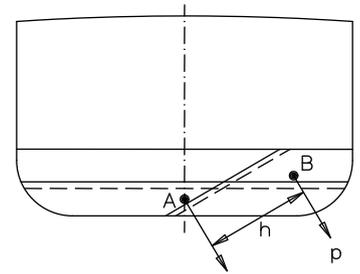
A - C.G. of the fluid cargo in even position

B - C.G. of the fluid cargo in heeled position

$M = P \cdot h$ – heeling moment from fluid cargo

M/Δ - correction of the GZ curve for the certain angle

For cases like this, the standard method of GZ curve correction by modifying the KG for free surface effect gives worse GZ curve than it is real. By stating the fluid cargo on data sheet dm2, the calculation of the free surface effect is done correctly.



b) A tank containing fluid cargo is damaged

Depending on the type and density of the fluid cargo and the position of the damage, various situations may occur. The program gives the following options to simulate the real flooding:

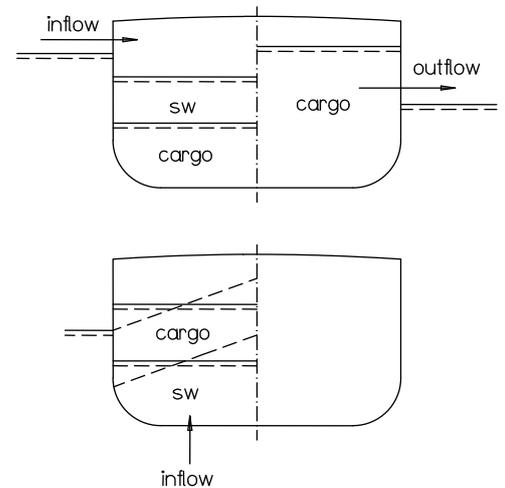
mix =0

density is changing linearly from ρ_{CARGO} to ρ_{SW} during the period of flooding

mix =2

$\rho_{\text{CARGO}} > \rho_{\text{SW}}$ cargo remains in the bottom and SW is flooded above

$\rho_{\text{CARGO}} < \rho_{\text{SW}}$ sea water floods into the bottom and the cargo remains above



For each compartment in data set **64** weight, density and % of filling can be given. Since the compartment volume is already calculated, one piece of information is too many. The following alternatives can be used:

- Weight and density are given. The program calculates the % of filling.
- Weight and % of filling are stated. Program calculates the density.
- Weight, density and % of filling are stated. Program uses % only to calculate the centre of gravity and moment of inertia. This option is used only in case when the builder has given the capacity figures and these should be used directly in the calculation. Sometimes, for various reasons, there can be differences between builder's capacities and the computer calculated volumes. If the builder's capacity for a compartment is 100 m^3 , the computer calculation gives 97 m^3 and the loading condition stipulates 98 m^3 of cargo in that same compartment, this obvious conflict is overcome by this alternative.
- Only % of filling is stated for number of compartments. An extra card is added at the end of the data sheet stating the weight. This weight is then distributed in relation to the filling and compartment volumes. Density is calculated as well.

N.B.

Values not stated are to be indicated by 0 on this data sheet.

Data sheet dm2a

This sheet is only an abbreviated version of data sheet dm2. It can be used only when no liquids are specified for tanks.

Data sheet dm3

Specification of each damage case

71 *dam. no* is an identification number. Normally the damage cases are numbered in sequence, but it's not necessary. It is possible to state decimals if it simplifies the classification of the damage cases. (When printing the final report it's possible to renumber the damage case.)

SB/P symm =0 indicates a symmetry damage (the calculation is done for SB heeling)

SB/P symm =1 calculation for SB heeling only

SB/P symm =2 calculation for PS heeling only

SB/P symm =3 calculation for SB and PS heeling

} asymmetrical damage

In the first two cases the program will calculate GZ curves for heeling only to SB side, in the third case, for heeling to P side and in 4th case, the program will create two independent calculations, one to SB side and one to P side. Figure 3 is used only when it's not clear if SB or PS heeling is critical.

crit no indicates which set of criteria described on data sheet dm5 is applicable for the damage case in question

numbers of loading conditions to be calculated ; normally each damage case is analyzed for all loading conditions. If, however, some damage case is interesting only for certain loading conditions, then the numbers of those conditions have to be stated here.

72 *compartment numbers* of damaged compartments can be given in any order. The same order has to be respected when stating subsequent data for permeability and flooding stages. The total number of simultaneously damaged compartments must not exceed 30. However, it is unusual to have more than a few damaged compartments.

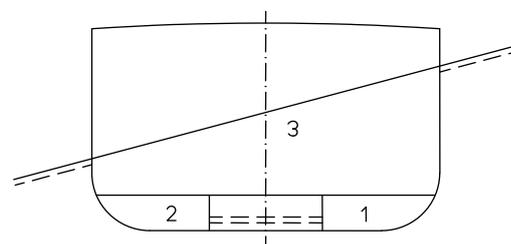
73 *permeability* has to be defined either here or on data sheet 7. It must not be stated in both places because the product of permeability is then used. If the permeability is given on data sheet 7, then zero has to be entered on sheet dm3. Also, it is possible to enter permeability for some compartments on data sheet 7 and for the others on data sheet dm3. If the same compartment has different permeability in different damage cases, it can be stated on data sheet dm3. Otherwise it would require description of the same compartment more than once, under different numbers, on data sheet 7. However, on data sheet dm3 only one permeability can be used throughout entire compartment - there is no possibility to define different permeability for different parts of the compartment. This is possible on data sheet 7.

74 *flooding stage factor* controls the rate of flooding in the different damaged compartments but only in a relative manner. By varying the factors for different compartments it is possible to vary the internal rate of flooding compartments damaged simultaneously.

Example:

Data given on data sheet dm3:

Compt.	1	2	3
Flooding factor	2	4	-2

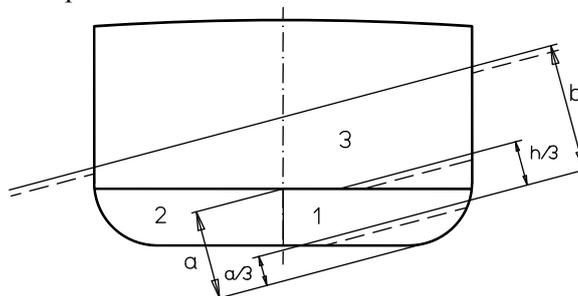


Negative sign indicates cross flooding. Cross flooding takes place first after the primary flooding is finalized.

The number of calculated stages of flooding is equal to the maximum number of specified flooding stages plus number of cross flooding periods i.e. 6 in this example. (In addition, the initial condition before flooding is calculated). The flood water level in each individual compartment is controlled by the flooding factor for the compartment in question.

There are two different categories of flooding. If the compartment is completely below the initial waterline, it will be totally filled, but if it is only partly below the waterline, it will only be flooded only the level of water outside the ship. In the following description a 1/3 flooded compartments means that it is flooded to 1/3 of the depth either

- to the top of the compartment or
- to the waterline b (b is the WL reached in preceding stage of flooding)



In the previous example, the compartment will be filled in accordance to the following table:

Flooding stage no.	Description	Compartment number		
		1	2	3
		Flood water level		
0	intact ship	0	0	0
1		1/2	1/4	0
2		2/2	2/4	0
3		2/2	3/4	0
4	final condition before cross flooding	2/2	4/4	0
5	cross flooding	2/2	4/4	1/2
6	final condition after cross flooding	2/2	4/4	2/2

N.B.

At calculation of the third stage of flooding, the final floating position is unknown. What is known is the draft - trim for stage number 2. The level 3/4 is therefore related to the position of the ship at the stage number 2. These remarks do not apply to the stages number 4 and 6. For those cases an intersection procedure is performed until the final position of equilibrium is found.

Complete GZ curves are calculated for all 6 stages in the example and could simulate the process where compartment 1 is damaged but also cross connected to compartment number 3.

Compartment 1 is filled quicker than compartment 2, for example because of the smaller volume and higher speed of the flood water. Flooding of compartment 3 will probably start before the final stage of flooding is reached for compartment 1 and 2. However, the new IMO regulation for passenger ships requires the calculation to be performed as described in this example. (Compare the flooding if the flooding stage had been = +10 for compartment number 3).

Another possibility, "delayed flooding" is obtained by adding a decimal to the flooding stage factor. Flooding stage factor = 6.4 indicates that no flooding takes place under the first 4 stages out of totally 6 stages of flooding.

Example

Data set	Data	
72	5	6
73	0.95	0.95
74	7	6.4
75	etc.	

Compartment 6 will be flooded during the 5th and 6th stage of flooding (flooded also in stage number 7).

75 *mix* is given only if the compartment contains liquid before damage. It has the same meaning as on data sheet dm2. It is given here only if there is a need to have a different value for mix for the particular damage case then what is given on data sheet dm2.

Extension to the flooding procedure

In addition to the above described flooding procedure some additional possibilities are available.

Factor *fproc* stated in data sheet dm1

Previously described flooding procedure has the disadvantage that the flooded volume varies for various angles of heel for the same flooding stage. Although the flooded water, when equalized outside the ship and inside the damaged compartments in final stage of flooding, is dependent on the final heeling angle, it might be more adequate to keep the flooded volume constant throughout the heeling. As an alternative to the previous method, the flooded volume is calculated exactly the same way as for the ship in upright position but kept constant throughout the heeling until the final stage of flooding when the level of flooded water in compartments is equalized to the WL outside the ship.

Possible alternatives:

- fproc* =0 (normally) flooded volume is constant at various stages of flooding except for the final stage
- fproc* =1 flooded volume varies with heeling angle
- fproc* =2 same as for *fproc* =0, but there is constant spacing in the amount of flooded water for the various stages of flooding

Optional data in data set 76

Data following after *mix* are optional. If entered, they should follow the same sequence as stated in the data sheet.

Omit or include *refp* and openings (*code* =1 and 2)

Series of points critical for the criteria evaluation is stated on data sheet dm4. These points can be opening, deck edge or margin line. In individual damage case sometime there is a need to reference to certain parts of these points or curves. There are two alternatives to indicate which points have to be considered:

- i* =1 all points of stated types are included except those specified here
- i* =2 only the stated points are included

Example

Code	Type	Points
<i>i</i>		
1	x	1-3 8 10-12 (omit points 1 2 3 8 10 11 12)
2	x	1 5 9 (include only the points 1 5 6 7 8 9)

Progressive flooding, spill over and spill out (*code* 11 and 12)

Common to all three alternatives

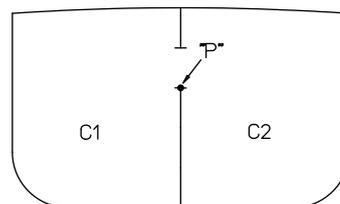
The following data are entered for data set 76:

Code C2 C1 fr dx y z

C1, C2 are the numbers of two compartments which have an open connection where flooding (spilling occurs) if liquid is above the point "P" defined with coordinates *fr dx y z*

N.B.

Flooding or spilling is calculated for each angle of heel independently e.g. flooding, spilling in previously calculated angles is neglected



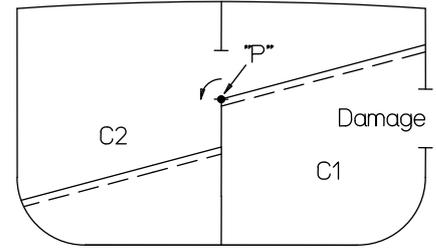
a) Progressive flooding

code =11

C1 is the number of damaged compartment

C2 is the number of undamaged, empty compartment

If the level of flooded water in compartment *C1* exceeds the point “P”, compartment *C2* will also be flooded (to the same level as *C1*). Compartment *C2* has to be empty before damage and with *flooding stage factor* =1.

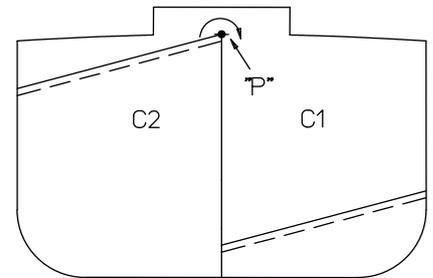


b) Spill over

code =12

C1, C2 are the numbers of two undamaged compartments

Compartment *C1* and/or *C2* contain liquid. If both *C1* and *C2* contain liquid then the density has to be the same. Liquid spills over from compartment *C1* to *C2* or from *C2* to *C1* when the level in respective compartment exceeds point “P”.



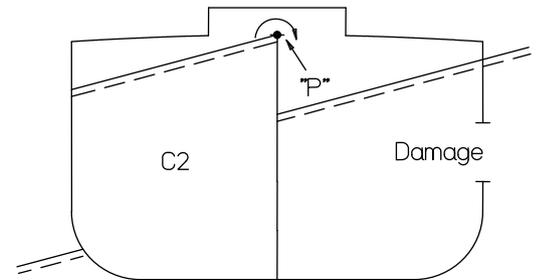
c) Spill out

code =12

C2 is the number of undamaged compartment; *C2* can contain fluid

C1 =0 which programs identifies as the sea

If liquid level in compartment *C2* exceeds point “P”, the liquid spills out. This option has to be used when “P” is an opening between the damaged compartment and the compartment containing liquid.



N.B.

This program requires that both compartment *C1* and *C2* must also be included in damaged compartments in data sets 72 – 75, even if they are not damaged.

Data sheets dm4 and dm5 - criteria evaluation

General comments

Data sheet is defined to show that critical opening and decks are not submerged in damaged condition. On data sheet dm5, criteria requirements are defined in detail. Program DAM1 reads input data sheets dm1, dm2, dm3. Program DAM2 performs the basic calculation. Program DAM3 including data sheets dm4 and dm5 evaluates the above mentioned data. Program sequence DAM1, DAM2 and DAM3 can be run at any time to evaluate the conditions or damage cases. DAM3 can also be run separately to review the calculated data for new criteria or modified reference points or opening. Symbol *i* indicates whether new or modified data on data sheets dm4 and dm5 are given or not.

Modified and extended definition of type of points

Although the data set 81 is left blank, it is possible to enter data which define the type of points stated in data set 82: The form of the data is:

- 81 *type of points* is the text describing the type of points
type =1, 2, 3 and 4 are already used by the program as follows:
type =1 reference points (margin line)
type =2 openings
type =3, 4 (special for passenger equivalent program)

Even the reserved numbers can be stated for changing the text (e.g. another language) but the meaning has to be kept.

Reference points and openings

- 82** *Frame no*, *dx*, *y*, *z* are the coordinates of the reference points
refl ; since program calculates damage heeling both to SB and P side it is necessary to indicate whether the points belong to SB, PS or both
type indicates the class of point

Criteria for damage stability sheet dm5

This sheet defines the criteria requirements. The principle is the same as from the intact stability program. There is, however, sometimes a need for different criteria for various damage cases (e.g. for symmetrical and asymmetrical flooding). Because of that, data is entered in the following form:

- Criteria set number followed by text
- Number of individual criteria items
- Next criteria set number etc.

Maximum 5 criteria sets can be stated and maximum 25 criteria items (lines on the data sheet). Also, maximum 10 criteria items can be stated for each criteria set. For each damage case a criteria number is stated in data set 71, data sheet dm3. This number refers to the criteria set number described here.

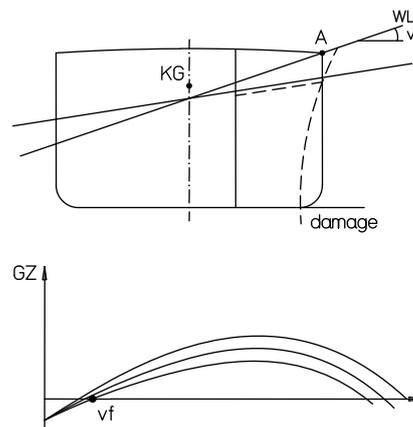
Purpose of the criteria evaluation is to calculate the required minimum GM or maximum KG for intact ship necessary to meet a certain requirement for the flooded ship.

Example

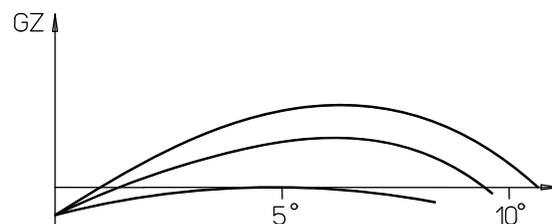
Wing tank is damaged and the criteria requirement is that point A shouldn't be submerged after flooding.

By heeling the damaged ship to different angles, it is calculated that point A will be submerged at an angle denoted ν_f . By varying the KG for the intact ship, a series of GZ curves for the damaged ship is obtained. One of them has $GZ = 0$ at an angle ν_f .

Corresponding KG value and GM for the intact ship are requested values. If, however, point A is submerged already at the angle $= 0$, no KG exists fulfilling the requirement.



There is another special case possible here. Suppose that point A is submerged at angle 10° . By lowering the GM for the intact ship step by step, the angle of list is increased until 5° list is obtained (see the sketch). After that the ship is unstable. This means that the ship can never get a list such that point A is just submerging.



In accordance with given input data GZ curves are calculated after flooding but also for a number of stages during flooding. The criteria analysis can be carried out for all these GZ curves. The GZ curve that requires highest GM for the intact ship will be decisive. If column 2 is set =0 on sheet dm6, the calculation will, however, be made only for the final stage of flooding.

There is various available criteria as explained in the further text.

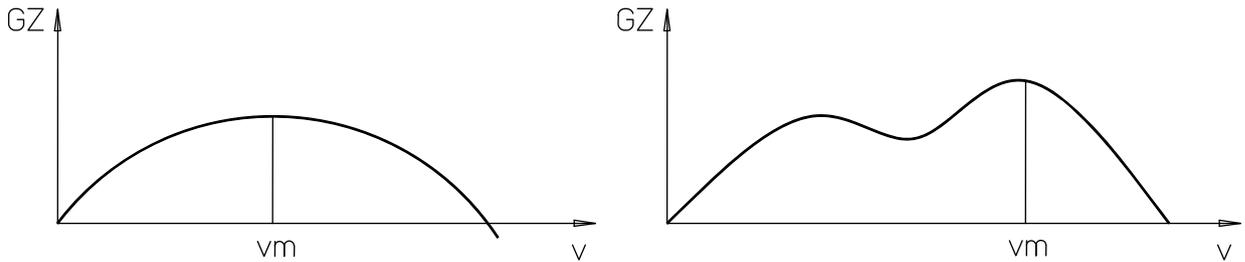
Symbols:

GZ righting arm in m or ft. GZ has the same unit as in hull data.

ν angle of heel

A area under GZ curve (in mrad of ftrad, see above explanation for GZ)

ν_m angle at which GZ obtains its maximum value



ν_f angle of heel when points on data sheet dm4 are submerged

ν_c capsizing angle

ν_r calculated range i.e. the last angle stated on data sheet sth. (In some cases the program might have failed to calculate all stated angles for a certain stage of flooding because draft – trim range has been given too small on data sheet sth. In that case $\nu_r = \text{max. really calculated angle}$)

Explanation of each criteria

Type 1

Reference points or openings shall not be immersed or maintain a certain distance from the damaged WL. Such GM which gives exactly the distance does not always exist.

Type 2

Required area under the GZ curve from the equilibrium position ν_l to the stated angle ν_1 .

Type 3

Required area under the GZ curve to the angle of flooding, ν_f .

Type 4

Maximum GM has to be within the defined range of angles 0 to ν_1 .

Type 5

Maximum GM has to be within the defined range of angles 0 to ν_f .

Type 6

GZ value at certain angle of heel.

Type 7

The slope of GZ curve at certain angle of heel. If the chosen angle =0 this criteria defines certain GM in the damaged upright condition.

Type 8

Slope of GZ curve at the equilibrium position of the damaged ship (GM in the damaged, heeled condition).

Type 9

Range of positive stability.

Type 10

Area under the entire positive GZ curve.

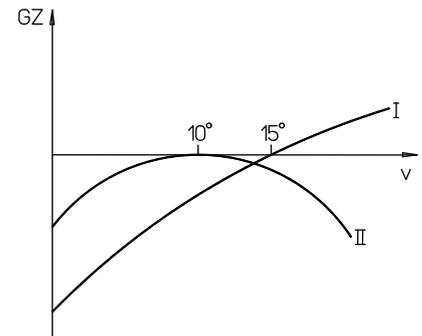
Type 11

Maximum angle of list. However, in some cases there is no equilibrium at the stipulated angle for any GM. (Compare to criteria type 1).

Example

Maximum angle of list = 15°.

For GZ curve I in the sketch there exists one intact GM value giving a list of 15° in the damaged condition. For the GZ curve II, however, the ship is unstable before reaching 15° heel. The answer in this case is the intact GM giving the heel of 10°. The criterion is called “max allowed angle of heel”. GM giving 10° angle of heel for curve II fulfills this requirement.



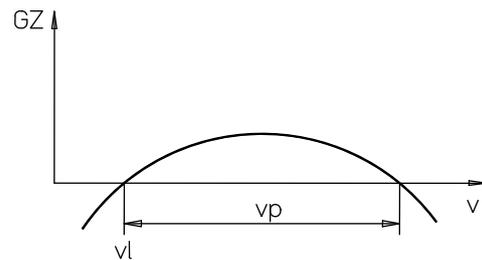
Type 12

Positive range beyond the position of equilibrium.

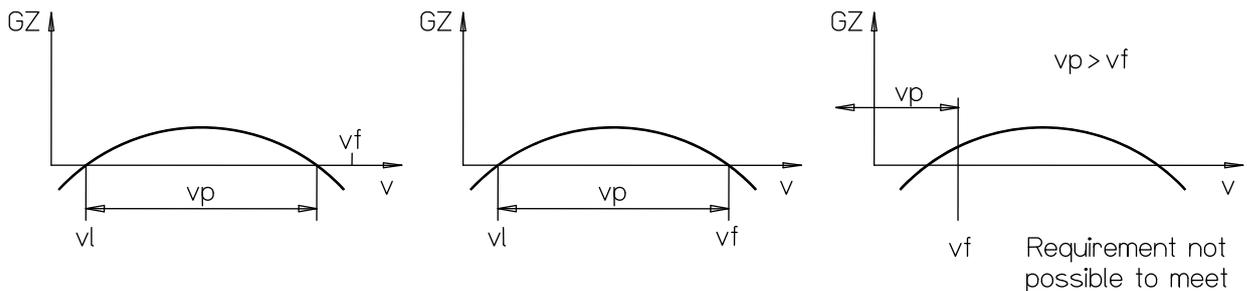
- v1 angle of list
- vf angle of flooding
- vp stipulated positive range

There are two alternatives:

Alt 1) Type of points omitted. No flooding.



Alt 2) Type of points stated. Flooding at angle of vf.



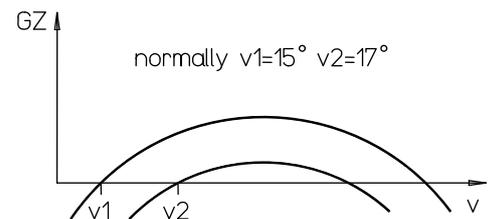
Type 13

Maximum angle of list depending on whether the deck edge is immersed.

- v1 maximum angle of heel if deck edge is immersed
- v2 maximum angle of heel if deck edge is not immersed
- v1 angle of list
- vf angle when deck edge is immersing; vf is calculated from the point types (normally 1) stated on data sheet dm4

Max allowed angle of list v1 as follows:

- a) vf < v1 v1 = v1
- b) v1 < vf < v2 v1 = vf
- c) vf > v2 v1 = v2



Type 14

Input for this criteria should have the following form:

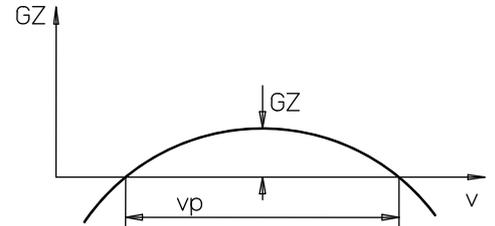
14 appl GZ vp

This criteria is a combination of two requirements:

- vp positive range beyond the position on equilibrium (vl)
- GZ righting arm which should be obtained within the above stated range

Example

Marpol requires $vp = 20^\circ$ and $GZ = 0.1$ m. The two requirements normally give two different GM values. The higher one is the answer.

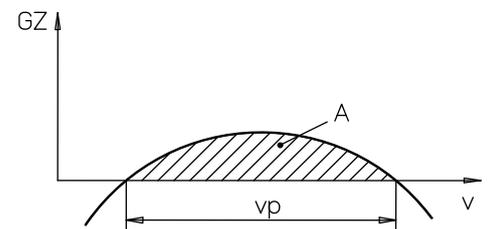


Type 15

Input for this criteria should have the following form:

15 appl A vp

This criteria is similar to criteria no. 14 with the requirement for GZ replaced by the requirement for the area below the GZ curve.



Data sheet dm6 – printing of final report for damage stability calculation

If some loading – damage cases are not relevant to the final report it is possible to state which loading conditions and damage cases will be printed. It is also possible to re-sequence the printout in relation to the calculation sequence.

Print codes are explained on data sheet dm6. It is recommended to give print codes 10 to 50 for normal runs and select one or more of the codes between 60 to 90 for special cases only. Decimal 1 is given when intermediate results are very important.

Program DAM4 can be run any time upon the previous run of program DAM3.

Old type of results

By stating:

ship no i 0 0 0 1

in data set **80** on data sheet dm4 the result for the previous version of program is printed.

Accuracy

Input on data sheet dm1 offers the opportunity to control the accuracy in the calculation. If blank card is left, default values will be used.

a1 a2 a3 control the accuracy for the final floating position

The final floating position is calculated by an iteration procedure. This iteration is terminated when the following requirement is fulfilled:

$$a2 * |drf - dr| + a3 * |trf - tr| < a1 * B, \text{ where}$$

B moulded breadth

drf, dr two consecutive draft values

rf, tr two consecutive trim values

Recommended and default values are

a1 = 0.001

a2 = 1

a3 = 1

Printing of intermediate results

P1 =1 gives moment for each compartment containing liquid. The moment = liquids moment due to the movement of the liquid at heeling

P2 =1 give details of the flooding calculation. Printout is very extensive therefore it is recommended to run just one specific loading – damage case when this printout is requested.

Loading conditions for intact ship (max 20)

loading case no description text of the loading case In the first column two numbers can be stated.
61

--	--

 In that case number 4 in group has to be used.

loading condition before the damage

62

1	ρ	d	t	CCG	KG	m
2	ρ	D	t	CCG	KG	m
3	ρ	D	LCG	CCG	KG	m

Description of symbols:
 ρ density of the sea water (ton/m³, or ton/cubft)
 D displacement
 d draft moulded
 t trim
 LCG longitudinal centre of gravity
 CCG centre of gravity from CL (pos. to SB)
 KG centre of gravity above BL
 m = 0 normally
 m \neq 0 includes liquid compartments from cond. m

62

4	ρ_1	ρ_2	d1	d2	t1	t2	CCG1	CCG2	KG1	KG2	m
---	----------	----------	----	----	----	----	------	------	-----	-----	---

 damage cases to be calculated for this condition (max 20; normally blank)

63

--

(N.B. data set **63** references only to damage cases given in previous run(s))

64

compartments with fluid cargo (max 30)				
comp no.	weight of cargo	density	% filling	mix
1				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
one blank line				

If KG is known and given above, a calculation for this KG value is done, results printed and the criteria from data sheet dm5 is used to check whether the loading condition meets the requirement. If the KG is unknown, leave it blank. The least permissible metacentric height is calculated and all curves of stability are calculated for this limiting metacentric height.

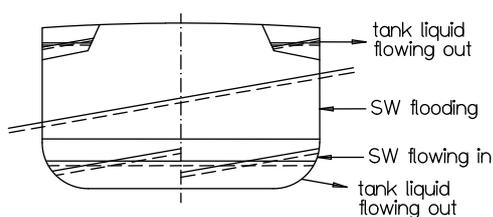
Curves of stability are corrected for free surface effects arising from specified fluid cargo.

Fluid cargo can be defined as follows:

1. weight and density are stated (% filling is calculated)
2. weight and % filling are stated (density is calculated)
3. weight, density and % filling are stated. The % is used only to calculate the centre of gravity and moment of inertia

mix = 0 density is changing linearly from ρ_{CARGO} to ρ_{SW}
 mix = 2 $\rho_{CARGO} > \rho_{SW}$ cargo remains on the bottom and SW is flooded above
 $\rho_{CARGO} < \rho_{SW}$ SW floods on the bottom and the cargo remains above

N.B.
 0 on the data sheet indicates values which are not entered.



Damage on SB side

The sketch demonstrates three different effects which are all correctly treated by the program:

1. Heeling moment from moving liquids (portside)
2. Tank liquid flowing out and SW flowing in
3. Tank liquid flowing out

N.B.

Permeability for compartments with fluid cargo (specified on this sheet) must be given on sheet 7 and not on sheet dm3.

Loading conditions for intact ship

This sheet is only alternative to sheet dm2. It is used when there is no fluid cargo.

loading case no	description text of the loading case					
61						
	alt	ρ	d or D	t or LCG	CCG	KG
62						
	one blank line					
	one blank line					
61						
	alt	ρ	d or D	t or LCG	CCG	KG
62						
	one blank line					
	one blank line					
61						
	alt	ρ	d or D	t or LCG	CCG	KG
62						
	one blank line					
	one blank line					
61						
	alt	ρ	d or D	t or LCG	CCG	KG
62						
	one blank line					
	one blank line					
61						
	alt	ρ	d or D	t or LCG	CCG	KG
62						
	one blank line					
	one blank line					
	one extra blank line					

- alt given
- 1 draft and trim
- 2 displ. and trim
- 3 displ and LCG

Description of symbols:

ρ density of the sea water

D displacement

d draft moulded

t trim

LCG longitudinal centre of gravity

CCG centre of gravity from CL (pos. to SB)

KG centre of gravity above BL

Each group has to followed with two blank lines.
The last loading condition has to followed with an extra blank line.

Damage cases

	dam no	SB/P	crit no	acc code	load. blank	cond. – all conditions calculated	to calculate - max 10
71							
72							
73							
74							
75							
76							
76							
76							
one blank line							

comp
Compartment numbers refer to those used on data sheet 7. Max 30 comp. in one damage case.

perm
Permeability can be given either here or on data sheet 7. If perm. is already given on data sheet 7, enter 0 here. For comp. containing fluid cargo perm. must be given on data sheet 7.

flood. stg.
Flooding stage factor controls the flooding, see below. If a “/” is entered instead of this line the program will use the flooding stage factor stated on data sheet dm1.

	dam no	SB/P	crit no	acc code	load. blank	cond. – all conditions calculated	to calculate - max 10
71							
72							
73							
74							
75							
76							
76							
76							
one blank line							
one extra blank line							

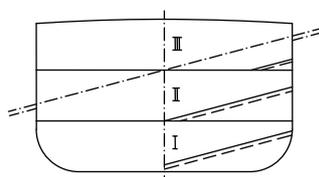
mix
For compartment containing fluid cargo this factor has the same meaning as on the data sheet dm2. This factor (if given) replaces the value on sheet dm2 for this damage case..

optional
Different data can be stated regarding:
a) reference points and openings to be included/excluded
b) coordinates for points through which progressive flooding takes place
c) data for special versions of the program (IMO A265 passenger equiv. program)

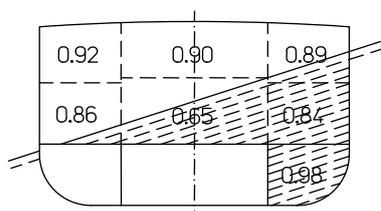
Typing:
Line flood. stg. and mix can be replaced with “ / ”.

Program procedure

Results are obtained during and after the end of flooding. If flooding stage factor is 4, calculation for one damaged compartment is made in 5 different stages – first one before flooding, second upon the 25% of flooding, then 50%, 75% and finally after the flooding. A neg. number for flooding stage factor indicates that the comp. should be flooded first in the stage of counter flooding. Normally state -1 for all counter flooded compts. Max number of flooding stages including counter flooded is 12.



If compartments I, II and III are separately, three free liquid surfaces, one above another occur during flooding. If I, II and III are described as three parts of the same compartment on data sheet 7, calculation is made only for one surface.



Any compartment, however complicated, can be treated by the program. True variation of permeability in the compartment with its influence on the heeling moment can be treated correctly by describing the compartment as a number of parts on data sheet 7 with varying permeability.

Damage stability

ship no i i =0 when data sheet dm4, dm5 are enclosed
80

		0	0	1
--	--	---	---	---

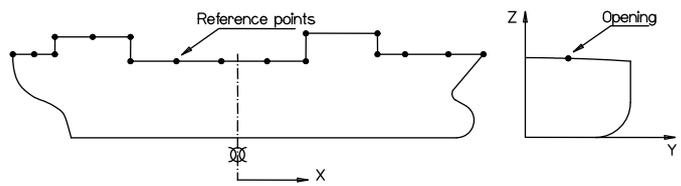
 i =1 when the following data are omitted (same as for the previous run)
 (Set of numbers 0 0 1 after the i value gives the old result.)

modified and extended definition of the type of points (explanation in user's guide)
81

one blank line

reference points and openings

	frame no	dx	y	z	refl	type	text – maximum 40 symbols (optional)
82	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						
	20						
	21						
	22						
	23						
	24						
	25						
	26						
	27						
	28						
	one blank line						
83	one blank line						



type =1 reference points (e.g. margin line)
 type =2 openings
 refl =0 regarded only the side of the stated point (SB or P)
 refl =1 the point is regarded on both sides, SB and PS (but given on SB side only)

Example
 For margin line 0.076 m below the described deck give $\Delta z = -0.076$.

Criteria for damage stability

Maximum 5 sets and 25 criteria items:

crit. set no.	description text of the criteria set				
	crit. type	appl.	parameters		
p1			p2	p3	p4
90					
	one blank line				

Criteria consists of one or more items explained in sketches below.
 For 0 in column 2 the criteria applies only to primary flooding
 For 1 in column 2 the criteria applies also during the flooding.
 For 2 in column 2 the criteria applies in the final stage of flooding (after cross flooding , if any).

Symbols

- GZ righting arm in m or ft
- v angle of heel in degrees
- A area under GZ curve in mrad of ftrad
- vm angle at which GZ obtains its maximum value
- vf lowest angle of heel when any given point type is flooded
- vc capsizing angle (angle of vanishing stability)
- vr upper limit for calc range of angles of heel

Criteria description

- Criteria 1 least distance p1 above the flooded waterline of the reference point type=p2
- Criteria 2 area under the GZ curve up to the given angle v1
- Criteria 3 area under the GZ curve up to the given angle vf
- Criteria 4 maximum GZ in given range of angles 0 to v1
- Criteria 5 maximum GZ in given range of angles 0 to vf
- Criteria 6 GZ at given angle v1
- Criteria 7 GZ' at given angle v1
- Criteria 8 GZ' at angle of list
- Criteria 9 positive range of GZ
- Criteria 10 area under the whole positive GZ curve
- Criteria 11 maximum allowed angle of list
- Criteria 12 positive range before flooding openings
- Criteria 13 maximum list =v1 if points are immersed
 maximum list =v2 if points are not immersed

Note:

- Criteria 1,3, 5: if $vf > vr$, vf is used as vr (vf is set equal to vr)
- Criteria 2: if $v1 > vc$, A is calculated to vc
- Criteria 3: if $vf > vc$, A is calculated to vf

Criteria parameters table

criteria type	parameters		
	p1	p2	p3

		asymmetrical flooding		symmetrical flooding		
1	dist.	type of points				"*****" is printed for GM if submerged in upright position
2	A	v1				
3	A	type of points				submerged in upright position

4	GZ	v1		
5	GZ	type of points		submerged in upright position
6	GZ	v1		v1 > vr
7	GZ'	v1		v1 > vr
8	GZ'			
9	v			v > vr
10	A			
11	v1			
12	vp	type of points		
13	v1	type of points		
14	GZ	vp		
15	A	vp		

Printing of final report

ship no
101

i in numbers of loading conditions to be printed or omitted
102

i in numbers of damage cases to be printed or omitted
103

- i =0 indicates that all loading conditions have to be printed
- i =1 indicates that all stated conditions have to be printed
- i =2 indicates that all stated conditions have to be omitted

The same applies to j for damage cases:

- in =0 normally
- in =1 loading conditions are renumbered in the sequence (1,2,3, etc.)

The same applies to jn for damage cases.

Ex.: i=0, j=0 will print all loading – damage cases.

For i=1 and j =1 the printing sequence will be the same as stated above.

For alternatives 0 and 2 the sequence used in calculation will be also used in printing.

print codes – tables will be printed in the sequence defined here
103

Print codes	Printed results
10	Summary of results. Overall GM requirement, angle of heel, deck immersion etc. for all loading – damage cases.
20	Detail description of the basis (input data) for the calculation.
30	Gm requirement for each criteria item. (30.1 gives GM requirements for all flooding stages)
40	Angle of heel to immerse the lowest points of any type.
41	Angle of heel to immerse the lowest points type 1.
42	Angle of heel to immerse the lowest points type 2.
50	GZ curves corresponding the intact KG stated in input
51	GZ curves corresponding the intact KG =0
52	GZ curves corresponding the intact KG = intact KM
53	GZ curves corresponding the intact KG = max. allowable KG according to the criteria evaluation
60	Draft (from keel to WL at amidships)
70	Trim (on perpendicular length)
80	Displacement
90	LCG (from amidships)

} distance to WL for the angle of heel is also printed

N.B.

Result according to the above print codes is printed for the final stage of flooding. By stating decimal =1 on the printing code, all stages of flooding are printed (not applicable to codes 10 and 20).

5.2 Subdivision and damage stability for passenger ships (IMO A265)

5.2.1 Summary

This special version of the Seaking damage stability program has been developed to enable the calculations for passenger ship. Data sheets 8P – 10P are used for description of relevant damage cases. However, data sheet 8a is omitted and the GM criteria in accordance with the regulation 5 is created by the program. The result of the damage stability is printed in such form that all requirements in the IMO regulations can be easily checked by the reader.

In the second step of the calculation the total GMR (regulation 5) and the R and A values are evaluated. (For “R” see regulation 2 and for “A” see regulation 6). For these calculations some additional data are required. They are filled in the enclosed data sheet dam3p and dam4p. The “x” values (x1 and x2) for each compartment are used for the calculation of “a” and “p” in the formula regulation 6 (a) (1). The “s” values in the same formula are calculated for the damage stability result saved on disc by the program described above.

The “A” calculation can be based on the minimum GM requirement calculated from regulation 5 or on GM values given as input data. This means that the variation in “A” due to variation in intact GM can be calculated. (Corresponding possibilities also for variation of freeboard).

5.2.2 Required input data and calculation procedure

Data sheet dam3p

Gives all information necessary for calculation of “a” and “p” coefficient in E a p s. (the calculation is very straight forward and not specially treated here). The information is also sufficient for calculation of “R” and for calculation of which part of the ship has to fulfil the two compartment standard.

Data sheet 8P

For each damage case there is a need to specify the relevant bulkhead deck. In order to reduce the amount of input data the coordinates for all alternative relevant bulkhead deck are stated on sheet 8P. The relevant bulkhead deck for the damage case in question is then defined on data sheet 10p by referring to the relevant lines on sheet 8p.

As a series of down-flooding openings are stated for all opening through which serious down-flooding could occur, see reg.1(h). For a specific damage case, one or more of these openings can lead to the compartments which are already flooded and for this reason are not dangerous openings in this respect. On sheet 10 (the last line in each group) is therefore specified which opening are serious for the damage case in question by referring to the corresponding index on sheet 8P. If it is easy to find from the plan which opening will flooded first, only this needs to be stated. However, a maximum of 8 openings can be stated for each individual damage case and the program searches for the most critical one.

Data sheet 9P

The first two data *ds* and *do* represent “subdivision draft” and “lightest service draft”.

N.B.

Moulded values should be entered in accordance with reg.1g.

GMR calculation in accordance with regulation 5 is performed for all conditions specified on data sheet 9P.

The A calculation is based on the first three specified conditions on sheet 9P which should correspond to the three drafts *d1*, *d2* and *d3* in regulation 1g(iii).

The calculation of the effect on GZ curve from liquids in tanks is not mentioned directly in the regulation.

This option in the program will probably not be used but it is available for special cases or when administration should require a very correct calculation (use the normal standard in the Seaking package). In regulation 5e it is stated that if $(ds-do) < 0.1ds$ and there are no discontinuities, the calculation for $d1$, $d2$ and $d3$ is not required, in which case they are interpolated from the results of the drafts ds and do . This possibility is not used in the program for the following two reasons:

The interpolation always means an approximation which probably is not justified in an accurate computer program.

It gives the user extra difficulties to decide whether the discontinuities mentioned in 5e have to be taken into consideration or not.

The extra draft - trim alternatives stated in addition to the three loading conditions $d1$, $d2$ and $d3$ are to be calculated in order to fulfil regulation 5(a), the first two lines that say "Sufficient intact stability shall be provided in all service conditions so as to enable the ship to comply with the provisions of the regulation". Naturally all combinations of draft - trim are impossible to calculate. The naval architect has however to add a few extra loading conditions which he feels are required to be analysed in regulation 5. Firstly, of course the extreme drafts ds and do which are proposed as condition 4 and 5 on the data sheet. In addition thereto it might be reasonable to add one or more drafts combined with trim values which make the damage situation more onerous. E.g. damages in aft end of the ship in combination with aft trim.

Trim to be used for calculation of A i.e. specified for the first three conditions ($d1$, $d2$ and $d3$) depends on the service trim for the ship. Many times the service trim is so small that the influence on the A values can be ignored and the calculation can be limited to even keel. If the ship sails with various trims which have to be taken into consideration there are two possibilities:

alt.(a) Search for each damage case the intact trim (in the range of service trim for the draft in question) which gives the lowest "s" values. Use these "s" values for the calculation of A.

alt (b) Base the "s" and A calculation on the particular trim (which can of course be different for the three drafts $d1$, $d2$ and $d3$). Repeat the complete calculation for various trim assumptions. A series of A values are obtained and if all of them meet the requirement (R) the ship is accepted.

The program does not cater for alternative (a).

This alternative gives in fact a lower A values than than real A value for any service - trim condition.

However, experience will probably show that one calculation in accordance with alternative (b) will be sufficient for most ships for which this regulation applies.

Data sheet 10P

All one compartment damages have to be stated here. Normally, all two compartment damages are also stated. Three and more compartment damages are stated only if any credit to the A value is expected. If it is known beforehand that A will have enough value without the credit from three and more compartment damages, these damages can be omitted.

To enable a correct linking of the a, p values (reg.6-a-1) with corresponding "s" values the damage cases have to be numbered in a special way contrary to the case in a normal calculation for damage stability. The damage cases are numbered in such a way that the number itself identifies which part of the ship is damaged. E.g. 11.3 means damage of three compartments from no.11 and forwards (decimal figure states number of flooded compartments and the integer figures the number of the aft most damaged compartment). From this point of view the main compartments of the ship are understood to be numbered in sequence from the aft to the fore end of the ship. The compartment numbers here discussed are the numbers of the main compartments and have only the function to link to the correct $x1, x2$ values stated on the data sheet, page 10. The compartment numbers used in the description of all separate tanks and compartments (data sheet 7) for the damage stability evaluation are fully independent from the above mentioned numbering system.

In accordance with the regulation, damages with smaller penetration have also to be analysed as to whether they give higher GM requirements or lower "s" values. For this reason it might be necessary to state more damage alternatives for one and the same combination of main compartment damages. To enable identification of these alternatives another decimal can be added to the number of the damage case. E.g. 17.31 17.32 17.33 17.34 identifies four alternative damage pictures of the three compartment flooding into the main compartments 17, 18 and 19.

The program chooses the most onerous alternatives for the calculation on GMR and “s”.
(N.B. There can be different cases which are most onerous for GMR resp. “s”)

There are sometimes in the new regulation which must be catered for by stating a few extra data for each damage case on sheet 10P. The information on this sheet is treated step by step. It is however assumed that the details of the Seaking standard damage stability program are known.

65 *reg.6*; in regulation 5b(ii) is stipulated to which extent the ship has to meet two compartment standard. Based on this formula and the first decimal stated for the damage case in question the program identifies if regulation 5 applies or not. There are however damage alternatives necessary for *reg.6* – calculation which, even though *reg.5b(ii)* applies, still need not meet *reg.5* due to the fact that regulation 5b(i) does not apply i.e. penetration inside B/5 or longer damage than the damage length. For such particular damages it is necessary to state *reg.6* =1 in input to control the program in avoiding *reg.5* – calculation for the damage in question.

r, *a* and *p* are defined in *reg.6b*, *reg.6c* and *reg.7b* respectively. These values are normally left blank and the program calculates *a* and *p* from the given input data as described above. The purpose with the option to stipulate *r* or *a* and *p* values (N.B. either *r* or *a* and *p* has to be given) is to enable calculation for the longitudinal and local subdivision. In A265, pages 100-114 such examples are given.

r is stated

The program calculates *a* and *p* in normal way but the *p* value will be multiplied by *r* before addition of “*aps*” in accordance with *reg.7(b)ii*. If the damage describes penetration inside the bulkhead, the values (1-*r*) should therefore be given in the box for *r* on the data sheet.

a and *p* are stated

The program uses these values in the calculation of the sum of “*aps*”. A special program will be developed calculating *a* and *p* for such cases as described in A265 but it has been deemed preferable to leave these compilations outside the general program for the complete evaluation.
N.B.

In addition to the above there is another difference in the calculation when “*r*” or “*a*” and “*p*” are stated. AS mentioned before more damage alternatives can be stated for one and the same main compartment(s) and the program uses only the lowest “*s*” values at the calculation of A. When *r* or *a* and *p* are stated the program however adds all the damage cases at the A calculation. This has to be considered carefully at the preparing of the input data. The program indicates an error if for one and the same compartment combinations there is given damage cases both with and without *r* or *a* and *p* value.

66 *compartment numbers and permeability*; regarding compartments it should be noted that the regulation limit the flooding picture to one free surface in a vertical direction (*reg.5b(3)*). For this reason compartments with various permeability placed above each other should be described as one compartment but with different permeability for the different parts (divided up on different lines in data sheet 7). Permeability is chosen in accordance with regulation 4.
For cargo spaces the permeability is a function of the draft.

$$\mu = 1 - \frac{1.2 * (d_i - d_o)}{d_s} - \frac{0.05 * (d_s - d_i)}{d_s - d_o}$$

but with the restriction $0.6 \leq \mu \leq 0.95$.

For cargo spaces the program evaluates the permeability in accordance with the above formula in perm is stated =-1 on data sheet 10.

N.B.

67 *permeability* has therefore to be left blank on data sheet 7 for such compartments.

68 *flooding stage factors*; the regulation stipulates requirements for two different stages of flooding.

- During intermediate stage of flooding. The angle of list must not exceed 20°, righting arm not less than 0.05 m and progressive flooding must not take place.
- In the final stage of flooding (after equalization). A number of requirement, see *reg.5*. The meaning of there flooding stage factor is described before.

Example

compartment 1 is given ***flooding stage factor*** =5

compartment 2 is given ***flooding stage factor*** =-2

The complete GZ curve, angle of list etc. are calculated for 5 stages of flooding of compartment 1. The last stage corresponds to the final stage of flooding before equalization. Thereafter are two further stages calculated when compartment 2 is half equalized and fully equalized. This meaning of ***flooding stage factor*** is used in order to fulfil the regulation in the following way. If the intermediate flooding could be most onerous, state a figure of say 5 for ***flooding stage factor*** for the primary flooded compartments which means that 5 intermediate stages will be analysed with respect to item 1 above. (If intermediate flooding is deemed not required to be analysed, state figure 1 as ***flooding stage factor***). For equalization compartments, state ***flooding stage factor*** =-1. Any intermediate stages during equalization are hardly necessary to be analyzed. If input data are stated properly in accordance with the above, the program calculates the required intact GM to fulfil the requirement in reg.5. The maximum value of these various GM values in the total GM requirement for the loading - damage case in question. In addition the data required for the “s” calculation in reg.6 is calculated and stored on the computer disc.

Regulation 5c(3) states “except in way of the flooded compartment or compartments no part of the relevant bulkhead deck at side shall be immersed”. However for the evaluation of F1 in accordance with regulation 1h the flooded length ship is included in the calculation.

The two above mentioned items make it necessary to give two lines on sheet 10P for bulkhead deck only and that the program could omit the part “in the way of flooding” from the information stated as x coordinates on sheet dam3p. However, if the bulkhead is stepped this is not possible. By preparing the bulkhead deck information in data sheet 8P with regard to its use on data sheet 10P the required information on sheet 10P is straight forward and reasonable in amount.

Regarding the F1 calculation note that the program automatically omits the parts of the relevant bulkhead deck outside 2/3 Ls if these are included in the in the input information. The program excludes also the area above 0.2 B2.

Damage stability in accordance with IMO Assembly Resolution A265

54

ship no	nl	ns	0	0	0	1
---------	----	----	---	---	---	---

nl no of loading cases stated on sheet 9P
 ns no of damage cases stated on sheet 10P

55

p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
----	----	----	----	----	----	----	----	----	-----

normally blank

p controls printing of intermediate results
 r controls shortening of printout

56

r1	r2	r3	r4	r5	r6	r7	r8	r9	r10
----	----	----	----	----	----	----	----	----	-----

Relevant bulkhead deck

Serious down flooding opening

57

	frame no	dx	y	z	type
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
One blank line					

type =4 points defining relevant bulkhead deck
 type =5 serious down flooding openings

Max of 75 point can be stated.
 All points type 4 have to stated before points type 5.
 There is reference on sheet 10P made to this table by stating the line index (to the left of this table).

N.B.
 Data sheet 8a is omitted.
 The criteria are set by the program itself in accordance with reg.6.

Description of loading conditions (IMO Assembly Resolution A265)

	ds	do	inew
60			

ds and do are the moulded drafts specified in reg.1.g.

	loading case no	description text of the loading case		
61	1	draft d1 in reg.1g		
	alt	ρ	d1	t
62	1			

alt: given:
 1 draft and trim
 2 displ. and trim
 3 displ and LCG

61	2	draft d2 in reg.1g		
	alt	ρ	d2	t
62	1			

61	3	draft d3 in reg.1g		
	alt	ρ	d3	t
62	1			

Description of symbols:
 ρ density of the sea water
 D displacement
 d draft moulded
 t trim
 LCG longitudinal centre of gravity
 CCG centre of gravity from CL (pos. to SB)
 KG centre of gravity above BL

61	4	draft ds in reg.1g		
	alt	ρ	ds	t or LCG
62	1			

First three conditions correspond to the drafts d1, d2 and d3 in reg 1g. These are used for calc. of A in reg.6.

61	5	draft do in reg.1g		
	alt	ρ	do	t or LCG
62	1			

After these three conditions such conditions are stated which might give higher GM requirement in accordance with reg5. Such conditions are of course drafts ds and do.

61				
	alt	ρ	d or D	t or LCG
62				

61				
	alt	ρ	d or D	t or LCG
62				

61				
	alt	ρ	d or D	t or LCG
62				

Loading conditions

loading case no description text of the loading case

61

--	--

loading condition before the damage

	ρ	d	t	CCG	KG	n
62	1			0.		

	ρ	D	t	CCG	KG	n
62	2			0.		

	ρ	D	LCG	CCG	KG	n
62	3			0.		

Description of symbols:

ρ density of the sea water (ton/m³, or ton/cubft)

D displacement

d draft moulded

t trim

LCG longitudinal centre of gravity

CCG centre of gravity from CL (pos. to SB)

KG centre of gravity above BL

n no of comp with specified fluid cargo, ≤ 50

compartments with fluid cargo				
	comp no.	weight of cargo	density	% filling
63	1			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	17			
	18			
	19			
	20			
	21			
	22			
	23			
	24			
	25			
	26			
	27			
	28	one blank line		

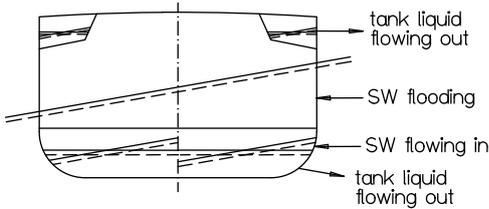
If KG is known and given above, a calculation for this KG value is done, results printed and the criteria from data sheet 8 are used to check whether the loading condition meets the set requirement.

If the KG is unknown, leave it blank. The least permissible metacentric height is calculated and all curves of stability are calculated for this limiting metacentric height.

Curves of stability are corrected for free surface effects arising from fluids contained in each specified compartment.

- Fluid cargo can be defined as follows:
1. weight and density are stated (% filling is calculated)
 2. weight and % filling are stated (density is calculated)
 3. weight, density and % filling are stated. The % is used only to calculate the centre of gravity and moment of inertia

- Damage on SB side
- The sketch demonstrates three different effects which are all correctly treated by the program:
1. Heeling moment from moving liquids (portside)
 2. Tank liquid flowing out and SW flowing in
 3. Tank liquid flowing out



N.B.
Permeability for compartments with fluid cargo (specified on this sheet) must be given on sheet 7 and not on sheet dm3.

Description of relevant damage cases (IMO Assembly Resolution A265)

←normally blank →

dam. case no. – normally controls calc. of a and p

reg.6 =1 if the damage need not reg.5

a ,p, r – see description

dam. case number	reg.6	r	a	p
65				
66				
67				
68				
69				
70				
71				
65				
66				
67				
68				
69				
70				
71				
65				
66				
67				
68				
69				
70				
71				
65				
66				
67				
68				
69				
70				
71				
65				
66				
67				
68				
69				
70				
71				

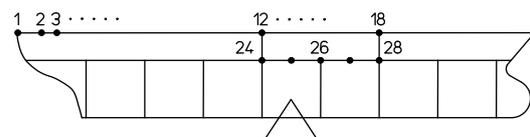
comp. nos. for damaged comp.
 permeability
 flooding stages
 relevant bulkhead deck
 relevant bkh deck clear of flooded comp.
 relevant openings

co.. comp. no.
 pe. refer to the numbers used on sheet 7.
 fl.
 bu1 permeability
 bu2 can be stated here or on data sheet 7
 op

flooding stages
 controls the calc. of intermediate stage, cross flooding, etc.
 co..
 pe.
 fl. bulkhead deck
 bu1 the first line is required for calc of the reg. 1,
 bu2 and the second time it is necessary for
 op requirement in 5c(i)(3) or 6(iii)

Each pair of stated numbers defines one part of the table on sheet 8P

Example:



The relevant bulkhead deck 1 – 12, 24 – 28, 18 – 23, but the part 24 – 26 in i the way of flooding. The correct input data is therefore:
 For line bu1: 1 12 24 28 18 23
 For line bu2: 1 12 26 28 18 23

openings

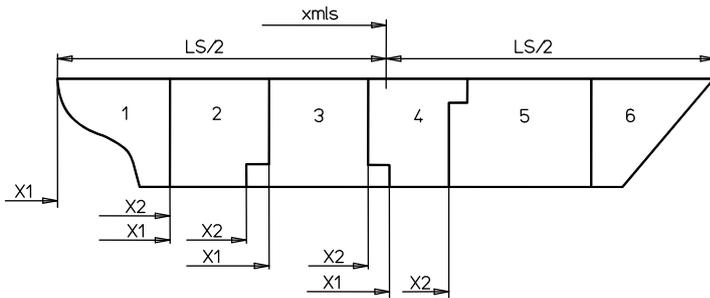
On sheet 8P all openings are stated. Here is stated which of these opening are serious.

Input data for subdivision calculation in accordance with IMO Assembly Resolution A265

LS	xm1s	B1	B2	N1	N2	N

	X1		X2	
	fr	dx	fr	dx
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
one blank line				

LS subdivision length as defined in reg.1c
xm1s x coordinate for centre of LS
B1, B2 breadths as defines in reg.1d
N1, N2, N passenger number as defined in reg.2c
X1 x coordinate for aft end of compartment
X2 x coordinate for fore end of compartment
X1 and X2 are stated be frame number and dx and gives in sequence from aft end forward.
As seen in the sketch X1, X2 for each compartment hast to be stated so X2 – X1 has a minimum.
Check is made in the program that X2 – X1 > lmin, see reg.5b.



Positive if forward of amidships
Negative if aft of amidships

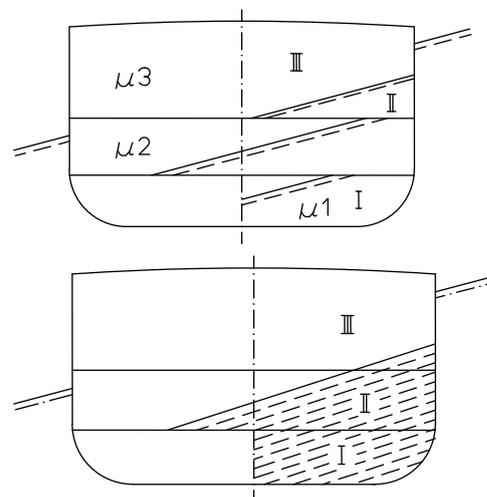
N.B.
The compartments are numbered from aft end.

5.2.3 Preparation of the compartment data for the Seaking passenger equivalent program

Description of compartments

Various options for flooding procedure in relation to data sheet 10 are described in user's guide for standard Seaking package.

If the three compartments I, II and III are described as three separate compartments on sheet 7, the calculation for intermediate stages will be as shown in the sketch.



If the three compartments, I, II and III are described as one compartment the effect will be one free surface only as shown in the sketch. Should the three compartments have various permeability they are described as three parts of the same compartment but with various permeability stated on data sheet 7.

One part of reg. 5b(iii) states "In all cases however only one breach in the hull and only one free surface need to be assumed". This means that the more onerous alt I above is not required and therefore use the procedure in alt II above.

The method to describe the various parts of the flooded space as one compartment (i.e. all information stated under the same compartment number) applies only for transverse directions and not for longitudinal direction. In fact, as the Seaking program does not consider the trimming moment effect of the trimmed WL inside the damaged compartment it is desirable to keep the damaged compartments as short as possible. For long single compartments it is therefore recommended to divide it longitudinally in two or more compartments (described under various compartment numbers on sheet 7).

Numbering of compartments

On data sheet dsm3p are the main subdivision compartments numbered sequentially from aft end and forward. From program point of view the compartment numbers used on data sheet 7 are completely independent of the mentioned numbers. However, it might be a good idea to choose the first figure in compt no equal to the no of the main subdivision compartment no.

For example compt-no 41 42 43 stated on sheet 7 describe various alternative flooding on main compartment no.4. If more than 10 alternatives are required, the number 401 402 etc. could be used. Compartments describing various flooding in main compt no 12 would be numbers 1201 1202 etc. There are probably other alternatives for systematic numbering of the compartments. What should be noticed is that a systematic procedure helps as well at preparing input data as at the checking of the calculation.

Some practical advice for performing the calculation

Step1 – searching for the most onerous flooding pictures

Both for regulation 5 and 6 the most onerous flooding picture inside the same main compartment(s) shall be used (for reg.5 however, no damage inside B/5). In many cases there can be a large number of alternatives. In order to save computer time it is therefore advisable to calculate various alternatives for one or two drafts only. Normally this result is sufficient for the decision of which alternative flooding should be used. It might be useful to tabulate required r values in the same run. This step can therefore be passed for ships with simple structure when there is no doubt in this matter.

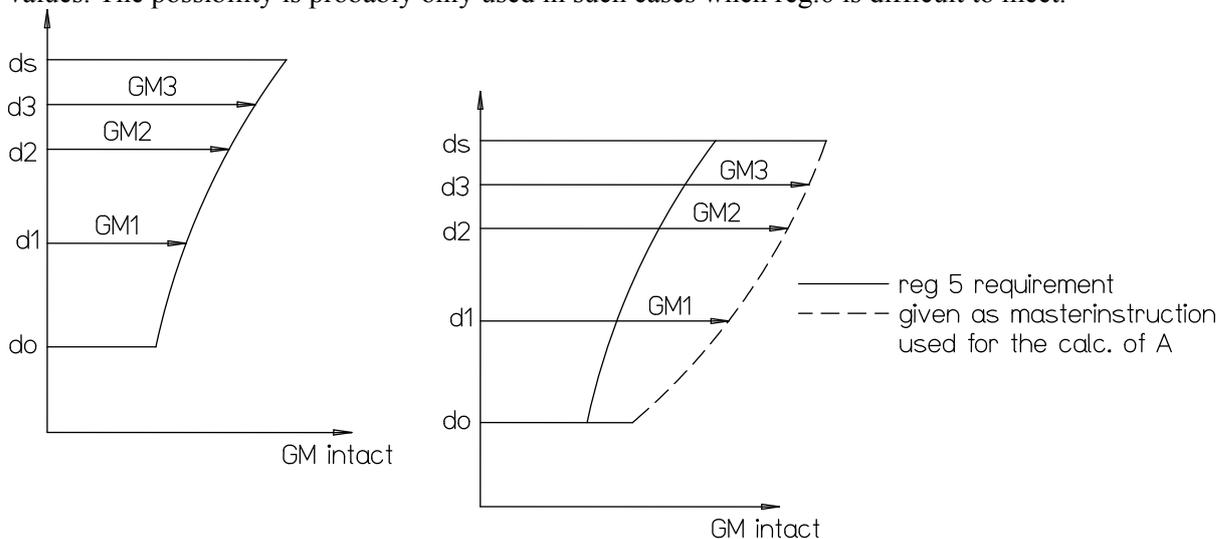
Step 2 – calculation of minimum intact GM to fulfil reg.5

Based on the result from step 1 a complete calculation is made in accordance with reg.5. Depending on draft range two to five drafts are calculated (d_0 , d_s and eventually d_1 , d_2 , d_3). The result from step 2 is analyzed and the GM versus draft is plotted.

Step3

Based on the result from Step 1 (and the r table if reg.7 is intended to be used) are the relevant damage cases prepared and run for the three drafts d_1 , d_2 and d_3 . The intact GM values used in the calculation can be taken from the plot in the Step 2.

However, if the plot in Step 2 indicates that the higher GM value is practicable for the ship, another curve can be drawn (GM master) corresponding to these practicable values. This curve is given only in the instruction to the Master and in accordance with reg.6d(i) the calculation of A is based on these GM values. The possibility is probably only used in such cases when reg.6 is difficult to meet.



5.2.4 Running procedure for Seaking passenger equivalent program

Running sequence

HULL74 (1 – 4)

STHYD (sty)

STABB

VOL1 (6, 7) restart for additional compartments

VOL2

VOLLC

DAM1P (8P,9P,10P) restart for additional or modified damage cases
(N.B. give correct value for *inew* on sheet 9)

DAM2P

DAM3P (dam3p)

DAM4P (dam4p) restart for additional calc. of A for alternative GM values

As seen above the running procedure is similar to the normal damage stability calculation.

The normal damage stability calculation result doesn't need to be saved in the computer after printing is completed. Any additional loading damage cases can be run at any later occasion independent of preceding runs.

However, for passenger equivalent calculation all damage calculating result has to be saved on disc for the final evaluation of all loading – damage cases. Because of this an extra variable called *inew* has to be stated on sheet 9P to control that the added or modified damages are saved correctly in the memory.

inew =blank for the very first run

inew =(1+no); if an additional damage cases have to be calculated “no” is the total of damage cases already saved on disc

inew =-no; “no” is the number of first damage case to be recalculated

Example

A total of 6 loading conditions have to be calculated for 40 damage cases. To enable investigation in steps the execution is divided in three runs, say 15, 15 and 10 damage cases in the three runs.

N.B.

All loading conditions have to be included at all runs. Assume that after the three runs it is observed that the damage cases 17, 18 and 24 have to be recalculated for some reason.

The runs will be as follows:

Run	Input data for program dam1	<i>inew</i>	sheet 10P for	damages
1	sheet 8P, 9P with	=blank	, sheet 10P for	15 damages
2	“ “ “	=16,	“ “	15 damages
3	“ “ “	=31,	“ “	10 damages
4	“ “ “	=-17,	“ “	damages 17, 18
5	“ “ “	=-24,	“ “	damage 24

If recalculation of compartments and addition of new compartments is required this can be made between any of the 5 runs above.

When all damage cases are properly calculated dam4p is executed. This program makes the final evaluation and printing in accordance with the regulations.

After examination of the finale result from dam4p it might be necessary to modify a few compartments. It is then also possible to use the above mentioned procedure and rerun only these compartments and corresponding damage cases and then run dam4p again.

If more A calculations are required for modified intact freeboard or GM, only dam4p needs to be run.

The principal in the above description is to run the complete calculation in one “go” but provide for the possibility to correct parts of the calculation without rerunning of the complete job.

However, experience has shown that in many cases it is more practical to do the calculation in several steps.

5.2.5 Criteria requirements

This section treats various criteria requirements for the passenger equivalent.

For reg.5 6 various Gm requirements are calculated

For reg.6 only 5 GM requirements are calculated

Different requirements apply to different stages of flooding. We define three different stages of flooding as follows.

Stage	Defines
0	Final stage of primary flooding but before equalization
1	Intermediate stages of primary flooding
2	Final stage of flooding (i.e. after equalization if any)

	Requirements in reg.5		assym flood	stage (see above)
1	Angle of list max 20 ⁰ GZ max not less then 0.05 m (or any other value stated as input to the program *)	X	X	0, 1
2	No progressive flooding	X	X	0, 1
3	Relevant bulkhead deck not immersed	X	X	2
4	Angle of list max 7 ⁰ or 20 ⁰	-	X	2
5	GM req. $0.003 \cdot B2(N1+N2)/(disp \cdot F1)$	X	X	2
6	GM reg. $0.015 \cdot B2/F1$ or 0.05m	X	X	2

*) The 13th input in the first data set on data sheet dam3p

- Angle of list max 20⁰ is stated in the regulation as follows:
Regulation Applies
5c (iii) Prior to equalization
5c (iv) During intermediate flooding
6d (iii) (1) During intermediate flooding or prior to equalization
- Progressive flooding, see regulation 5c(4)
- Relevant bulkhead at side shall not be immersed. Exception is made for the part in the way of the flooded compartment(s).
- Angle of list max 7⁰ for one compartment damages and 12⁰ for two compartment damages.
- GM in the final stage of flooding calculated in upright position minimum $0.003 \cdot B2(N1+N2)/(disp \cdot F1)$
- GM in final stage of flooding calculated in upright position not less than $0.015 \cdot B2/F1$ or 0.05m

Sequence 1 – 6 described above is the same as in the output.

Which damage should fulfill one resp. two compartment standard depends on the length of the ship, number of passengers and the longitudinal position of the compartments (see the regulation). This choice is automatically made by the program.

As seen above the only difference between asymmetric and asymmetric flooding regarding criteria is in fact the angle of list 7⁰ resp. 12⁰ which is not necessary for symmetrical damages. At symmetrical damages the positive GM req. in items 5 and 6 guarantees that no list will occur.

Requirement in reg.6 which must be fulfilled if credit to the value A for the damage in question should be allowed. These requirements, stated in reg.6d(iii), are automatically fulfilled for damage cases which have to meet reg.5 All other damage cases evaluated in order to get credit to the value A must however be evaluated in accordance with these requirements. If they are not met “s” has to be taken as zero i.e. no credit to the value A.

	Requirements in reg.6	symm flood	assym flood	stage (see above)
1	Angle of list max 20 ⁰ GZ max not less then 0.05 m (or any other value stated as input to the program *)	X	X	0, 1
2	No progressive flooding	X	X	0, 1
3	Relevant bulkhead deck not immersed	X	X	2
4	Angle of list max 12 ⁰	-	X	2
5	GM =0.05 in upright condition	X	X	2

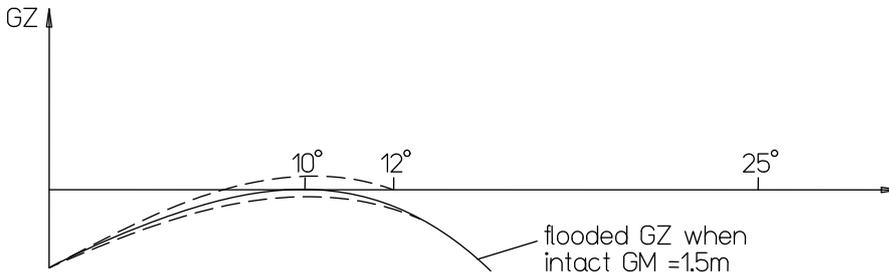
The sequence 1 – 5 described above is the same as in the input.

Explanation why several GM requirements are sometimes identical

At the first glance of the calculated GM requirement it is sometimes surprising to find exactly the same figures for very different criteria requirement. In most of such cases the explanation is very simple and will be explained with an example:

Assume that the following criteria required are requested.

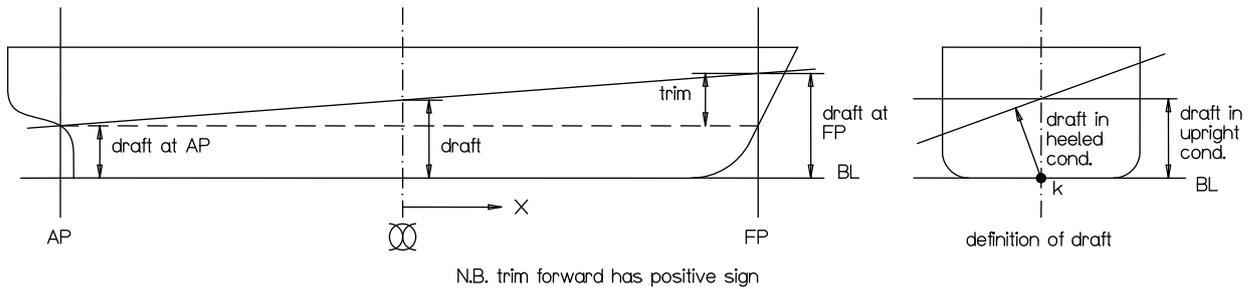
1. Bulkhead deck above flooded WL
(in this particular case bhd is flooded at 25⁰ angle of list)
2. Angle of list not more than 25⁰.
3. Progressive flooding not allowed.
(in this particular case the most critical opening is flooded at 15⁰ angle of list)



If the GZ curve in flooded condition is as shown in the sketch it is obvious that if intact GM is slightly more than 1.5 m the angle of list is less than 10⁰ and all the above requirements are met. On the other hand, if intact GM is slightly less than 1.5 m the ship is unstable and none of the above requirement is met. The correct GMR value is therefore =1.5 m for all criteria.

Another case of identical GMR values can occur when the final stage of flooding is more critical than the intermediate flooding and two identical criteria are requested, one including intermediate stages and the other final stage only.

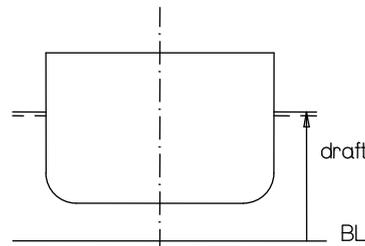
Coordinate system



The above sketch indicates the coordinate system used in all results. Draught is always the draught from BL if not otherwise specifically stated. The only exception from this rule is in fact the hydrostatic data, in which draught can be printed from BL or underside of keel. This definition of draught means normally moulded draught. However, if the BL for some reason is not placed at the bottom of the ship the above rule still applies as seen in the sketch.

Draught always refers to amidships. This means:

$$\begin{aligned} \text{Draught} &= 1/2 * (\text{draught at AP} + \text{draught at FP}) \\ \text{Trim} &= (\text{draught at FP} - \text{draught at AP}) \\ \text{draught at AP} &= \text{draught} - 0.5 * \text{trim} \\ \text{draught at FP} &= \text{draught} + 0.5 * \text{trim} \end{aligned}$$

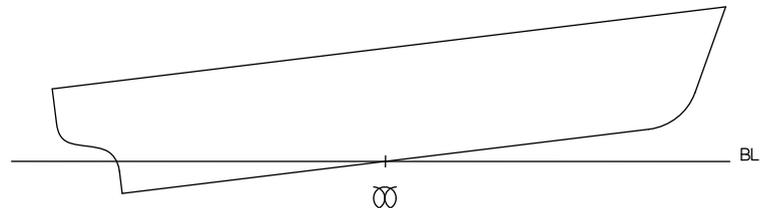


Therefore, trim by head is positive.

At hand calculation, draught at LCF is normally used but in the computer input and result it is corrected to the amidships position to make it more convenient for the user.

If the ship has a sloping keel the draught is still measured from BL amidships.

Normally the BL is so placed on the body plan that it passes the moulded line at CL amidships. Trim = 0 printed in the result means that the ship has the condition as stated on the body plan.



Consequently trim $\neq 0$ states the trim in relation to the condition stated on the body plan.

In some printouts frame no and dx are stated instead of the x coordinate from amidships. For example: no. 17 dx = 1.5 represents a point 1.5 units forward of frame 17. (Abaft frame 0, the frames are often numbered A, B, C etc., this should be altered to -1, -2, -3 etc.)

Comments to the output from calculation in accordance with IMO A265

The following pages give a description of the output from the Seaking program for damage stability calculation in accordance with the IMO resolution.

The output consist of the following parts:

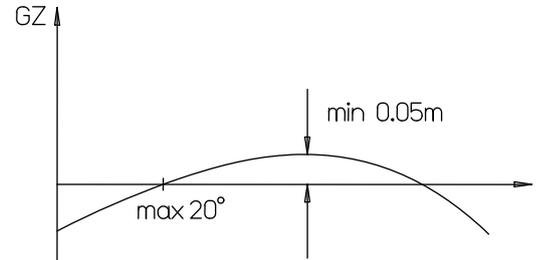
1. Reg.5 - calculation
2. Reg.6 - calculation
3. Damage stability calculation
4. Compartment capacities
5. Compartments definition
6. Hull form definition

Reg.5 – calculation

The first page (page 9) contains the transverse subdivision. Coordinate system used has been explained before. In the following pages, there is the GM requirement for a number of loading conditions. each page corresponds to one draft – trim position. In the first column there are all damage cases which have to meet reg.5. The GM requirement are printed in two groups during flooding and for the final stage of flooding.

The requirement during flooding are as follows:

- Angle of heel must not exceed 20° .
- The lowest GZ max not less than 0.05 m or any other values stipulated by the authority in question.
- Progressive flooding through serious down-flooding openings must not take place.
- The intact GM corresponding to these two requirements are found in the second and third column of the printout.



The requirement in this final stage of flooding are as follows:

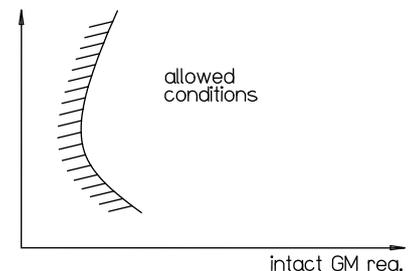
- Relevant bulkhead deck is not to be immersed. (N.B. that bulkhead deck in the extent of flooded comp. is allowed to be immersed)
- Angle of heel max 7° for one compartment damage and 12° for two compartment damages.
- The requirement in reg.5c(i): $GM = 0.015 \cdot B^2 / F1$ or 0.05 m whichever gives the highest requirement.
- The requirement in reg.5c(i): $GM = 0.003 \cdot (B^2 \cdot B^2 \cdot (N1 + N2)) / (\Delta \cdot F1)$ N.B. GM requirements and formulas apply for metric units only.

These four requirements are printed as one column each.

The “Max value” line resp. column indicates the overall GM requirement for each individual criterion resp. each individual damage case.

Note that only those damage cases which have to meet reg.5 are summarized.

The last page for reg.5 calculations contains a summary of minimum GM for the various conditions. From this sheet the limiting curve for allowed condition can be drawn as shown in the sketch. If the calculation is performed for a series of trims, corresponding number of curves can be drawn.



Reg.6 – calculation

The first page contains details for calculation of a in accordance to reg.6b. The next page lists the calculation of p . These p values are based on reg.6 only. The more complicated p calculation using reg.7 is not considered here. (The printout is self explaining).

The following pages give details for “s” calculation. Each damage case is repeated on three lines corresponding to the three drafts – $d1$, $d2$ and $d3$. In some cases it might be printed “s estimated to 1”. This means that the corresponding damage case has not been evaluated at all, due to the conclusion made by the program user that the damage case in question is not critical for reg.5 and must give $s = 1$ in reg.6 calculation.

The symbols used in the results correspond to the symbols in the regulation. The first column states the damage case number. Regarding numbering of damage cases see “page 9”. The next two columns state the freeboard $F1$ calculated from area and down-flooding openings. If “*****” is printed for the down-flooding, it indicates that no opening is flooded for the calculated range of angles of heel.

Theta (Θ), GMR and MMS see the regulation. The intact GM used for the “s” calculation can either be the minimum value fulfilling regulation 5 or a higher given as input. The regulation allows using higher GM if this is included in the Captain instruction. Which GM is used is printed on the top of the page.

The first “s” column states the “s” values calculated from formula 6d(i). However, reg.6d(iii) states further requirements which have to be met if contribution to the A calculation shall be allowed.

The second “s” column states the “s” value used in the A calculation and is therefore equal to the first column for such damage cases which meet reg.6(iii) and equal zero if this is not the case. It is not quite clear in the regulation whether the requirements in reg.5 for a certain righting arm during the flooding (0.05 m) should also apply in reg.6d(iii). It seems however logical to do so and this is also the way the program works.

For such damages when intermediate flooding is critical but final stage of flooding has good GM freeboard values it can occur that $s = 1$ in the first column and $s = 0$ in the second.

The “s” tables are ended by summary of the A calculation. In this summary there are only the most critical of alternative damages selected i.e. the damages with the lowest “s” values (in accordance to the requirement in the regulation).

The capital A in the printout should be an a in the table “a”, “p” “a*p” and “a*p*s”. Unfortunately the computer facility does not meet this need. The weighed “s” mean value is calculated from the formula $s = 0.45*s_1 + 0.33*s_2 + 0.22*s_3$.

Comp states the aftermost main compartment in the group. For example comp =3 in the 2 comp group means damage of comp 3 and 4. The final “Summary of A calculation” gives the values of E_{a*p} and E_{a*p*s} . Note that in the E_{a*p*s} are included only those damage cases which have been calculated (not calculated cases are assumed to have $s = 0$).

Damage stability calculation

Result displays the basic damage stability calculation on which the previous description of reg.5 and 6 calculations is based.

The first page states the input data for relevant bulkhead deck and serious down-flooding openings. The sequence numbers in the first column are used for referring to the relevant parts for each individual damage case. The following pages state the input data for loading condition and damage cases. This information is however repeated on the result pages for the detailed damage stability calculation.

Each following page displays the result of calculation for one particular combination of loading damage.

The pages are arranged in such a way that all loading conditions for one damage case are printed in sequence followed by the next damage case etc. The damage cases are normally arranged in such a sequence that all one compartment damages are printed first (from aft to forward) followed by all two compartment damages etc.

The printout begins with a specification of the loading condition and damage configuration.

The loading condition is specified by the draft, trim, LCG and displacement. If liquid loads in tanks are taken into consideration at the calculation of the GZ curves, these liquids are also specified.

The damage is specified by the numbers of the flooded compartments (the names of the compts. are also printed). Permeability and flooding stages =flstg are also printed. Flstg states the number of calculated intermediate flooding for the compartment in question. A negative number indicates that the compartment is filled first at the cross-flooding.

The next line specifies if the calculation is performed for reg.5 or reg.6 followed by the corresponding GM.

For damage cases which have to meet reg.5 the GM requirements GMR are listed in the same sequence as used on the previously described result of reg.5 calculation. For damage cases which don't have to meet reg.5 the GMR values correspond to the requirements in reg.6d(iii). The values are arranged in such a way that the first four values correspond to identically the same requirements as for reg.5. The fifth value corresponds to the requirement of (GMR-MMS) not less than 0.05 m in the final stage of flooding.

Each GM value is followed by a bracket and a number here denoted i. Normally $i = 0$.

For the first GMR value i.e. requirement on relevant bulkhead deck, “i” has the following meaning:

- $i = 1$ relevant bulkhead deck is above WL for all calculated angles of heel
- $i = 2$ relevant bulkhead deck is immersed also for the ship in upright condition
- $i = 3$ relevant bulkhead deck is not defined (on sheet 8P)

For the following GMR values $i = 1$ indicates that the calculated range is less than required for a correct evaluation of the GM in question.

Example

GZ curves are calculated only for the range $0 - 15^\circ$ and the GZ requirement of 0.05 m applies for the range $0 - 20^\circ$.

The program prints the intact GM to meet the 0.05 m requirement in the range $0 - 15^\circ$ although a lower GM could have met the requirement in the range $0 - 20^\circ$.

Conclusion

Index 1 printed after the bracket indicates that the printed GMR value might be higher than the real requirement.

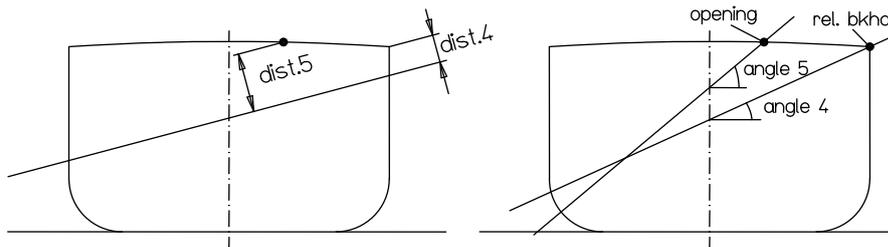
The largest of the GM values is of course the overall GM requirement. No more results need to be printed for the purpose of calculation of A and the overall GM requirement for the ship. However, to give further information on the behavior of the damaged ship additional information is also given.

All further information printed on the page is based on the assumption that the intact GM is just equal to the overall requirement for the particular damage case in question.

The GZ curve is printed for each calculated stage of flooding.

The first line corresponds to the intact ship before damage. The last line corresponds to the final stage of flooding. If there is a cross or counter-flooding arrangement the last line is the final stage after cross or counter-flooding and the preceding line the final stage before cross or counter flooding.

The following group of results displays the equilibrium position of the ship and the freeboard to relevant bulkhead deck and serious down-flooding opening. The information is printed for each stage of flooding numbered in the same way as for the GZ curves. Line "angle" states angle of heel when the lowest point is on the WL. Dist. depends on intact GM but angle is independent there (see the sketch below)



The last data describe the damaged ship in the final stage of flooding with the ship assumed to be in upright condition.

Compartment capacities

This table (tables give the volume for all compartments involved in any flooding calculation. Note that the permeability factors can be introduced either at the volume calculation (in which case the printed volume are already corrected) or at the damage stability calculation.

Compartment definition

These data consists of a number of tables followed by the description of the compartments. The compartment numbers stated in the damage stability result refer to the numbers used in the compartment definition.

Hull form definition

Normally the input data for hull form are checked by running a program which plots the body plan from the given input data. (The same method is also used for compartments.)

The definition of hull form and compartments is the same for these calculations as for the standard version of the Seaking program.

5.3 Damage stability program calculating the process of flooding in real time

5.3.1 Introduction

The existing Seaking program for damage stability has been developed and improved in a number of steps to provide the calculation of complete GZ curves and criteria analysis of any type of complicated damaged compartments and a wide range of criteria alternatives. Intermediate flooding stages can be analyzed and flooding on different decks with more than free surface vertically can be treated.

The stability at intermediate stages of flooding is analyzed by requesting of complete GZ curves when the compartment is partly flooded, for example to 1/3, 2/3 and completely. What is not possible to calculate is the time involved due to the fact that the size and position of the opening are not specified. The program described in this paper gives the possibility to study the flooding process in real time. In addition to the calculation of the time involved the program provides for study of a number of various mechanisms involved in the total picture of flooding. Such mechanisms are progressive flooding and the function of cross-flooding arrangements. There are options to state pumping capacities as alternatives to openings. As seen on the data sheets it is also possible to change openings and pumping capacities at any time interval. The effect of presupposed actions of the ship master at certain time intervals after the accident can therefore be studied in detail. The program can also be used for analysis of cases with no damage. Such an example is pumping water on the burning ship. The pumping of water on high decks and its flow down through the opening giving free surfaces on more decks causing bad stability can be studied. A few examples are shown at the end of the description.

5.3.2 Description of input data

The calculation is based on the existing Seaking program and data sheet 8 and 9. Data sheet 9 is very useful because it provides a detail description of the loading condition before damage. All mentioned data sheets are already described in previous chapters. The only new data sheet is "Data sheet 10 R for damage stability in real time" enclosed with the description. This data sheet replaces the data sheet 10 of the standard damage stability program.

One data sheet is filled for each damage case.

Usage of units and coordinate system is the same as explained before. For time, however, seconds have to be used generally. Units m or ft and ton are recommended.

90 *damage no* is an identification number of the damage in question

text will be printed as a heading in the result

91 $g = 9.81 \text{ m/s}^2$ or 32.2 ft/s^2

The following data on this data set controls the calculation. For detail understanding of these data it is necessary to study the enclosed "Theory of calculation method for damage stability program in real time". The first approach to the program was to write a 100% automatic program which should evaluate any type of problem with highest accuracy. Another demand to the program was that it should be capable to solve any problem in the field of the subject. It was possible to meet all those requirements except that the user has to give some parameter to control the calculation. With these parameters and the flooding question, the program chooses the relevant time step. The accuracy and computer time is directly depending on the time step. For this reason after each calculated time step it is evaluated whether the time step can be increased or has to be decreased.

The following four items are analyzed at the decision of increasing or decreasing the time step:

		limits	
		min	max
1.	Deviation in linearity for flooding	f1	f2
2.	Change in heeling during one time step	f3	f4
3.	Change in draft during one time step	f5	f6
4.	Change in trim during one time step	f7	f8

For each item min and max value is given. If all four items meet the min value, the time step for next calculation is increased.

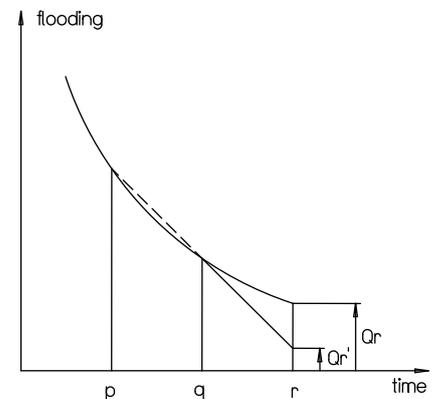
If any of the four items are above the max value, the time step is decreased. The calculated step will be recalculated in this case.

By choosing a suitable difference between the min and max values, the advantage will be obtained that the time step will be kept constant during certain periods of time. For the default values, the upper limit has been chosen =5*lower limit. It means that the time step will be decreased if during a time step change in heeling exceeds 0.5° or change in draft or trim exceeds 0.5 m.

From the enclosed description of theory it is seen that under some assumptions the flooding speed will vary linearly in respect of time. In this case the flooded volume during a time step will be correctly calculated by using the mean value of speed during the time interval. In the sketch Q_r defined the correct flooding and Q_r' the linearly interpolated value. The difference $|Q_r - Q_r'|$ is a direct information about deviation in accuracy. The factor f1 and f2 are related to the following:

$$\text{Max } |Q_r - Q_r'| < f1 * \text{total flow}$$

$$\text{Min } |Q_r - Q_r'| > f2 * \text{total flow}$$



The words max, min and total are relevant only at flooding through a number of openings. In the default values are used, the time step will be kept if $0.01 * Q < |Q_r - Q_r'| < 0.05 * Q$ where $Q = \text{total flow through all openings}$. Default values in the Seaking package can normally be used for most calculations. For this program, however, the user has to analyze the problem to be solved and give values which are relevant.

For the full control of the program, the user gives further information:

min = minimum time step

max = maximum time step

mult = multiplier for increasing or decreasing the time step

Tolerances for termination of the calculation are given for heeling angle, draft and trim. The calculation is terminated as soon as all three conditions are fulfilled for a time step. If the default values are used, the calculation will continue until change in angle, draft and trim are less than 0.02°, 0.002 and 0.002 m. In many cases the purpose of the calculation is to find the final floating position after e.g. equalization between various compartments.

In order to avoid loosing computer time due to the inappropriate data, some further data are given:

mstep defines number of time steps after which the calculation is terminated

maxtime defines maximum flooding time after which the calculation is terminated

mintime defines the time before the calculation will not terminate even if all conditions are met.

This possibility can be used to avoid that the calculation is terminated immediately due to the very small flooding during the first period.

It is very likely that the problem has to be run more times before the accurate result is obtained. After some experience, however, the user will easily give such control data which serves his purposes best.

The following codes describe the reason for calculation termination at execution of DAM2R:

Code	Termination due to
1	All activities ended (e.g. all openings are closed)
2	Max time exceeded.
3	Max number of steps exceeded (mstep)
4	All tolerances for equilibrium are met
8	Max number of extra loops exceeded
9	Oscillating condition
10	Outside calculation range of stability

92 *prin1* =1 gives printing of flooding through each opening (and part of opening) for each flooding time step.

93 *prin1* =1 gives printing of flooding through each opening (and part of opening) for each flooding time step.

type =1 indicates an opening between a compartment and sea or between 2 compartments e.g. a damage, a door opening or a window

type =2 indicates a “pipe connection” between two compartments or compartment and sea. The “pipe” can of course be any tape of connection.

type =3 indicates a pump. Pumping can take place between two compartments or between one compartment and sea.

room no =0 indicates the sea. As consequence thereof two room numbers are always given (the numbers refer to corresponding numbers on data sheet 7). Sequence n1, n1 in important only at pumping as this takes place from compart. n1 to compart. n2.

time t1, t2 t1 states the start time and t2 the end time. At t2 the opening is closed again or the pumping stops. If t2 is not relevant state t2 =0.

Opening ans type data

These data are different for the various types:

Type =1 opening between compartment n1 and compartment n2 during the time interval t1 – t2. Opening is described in form of one or more point openings. The coordinates are *frame no*, *dx* and *z*.

The opening area =*A* and contraction coefficient =: but only the product *zA* is stated in the input. It is necessary to divide the area in pieces only if the flooding speed varies in different part of the section i.e. considerable differences in the vertical distance to the liquids from various part of the section area.

Type =2 defines pipe connection between two compartments. The opening data (*fr*, *dx*, *y*, *z*, *zA*) are stated for compartment n1 and n2. The first *zA* states the contraction coefficient and area when flooding from compartment n1 to n2 and the second value when flooding from compartment n2 to n1. The end coordinates control the flooding e.g. in the sketch no flooding takes place due to the fact that the point II is above water level. The program cannot consider such cases as shown in the sketch as only the end points of the pipe are specified.

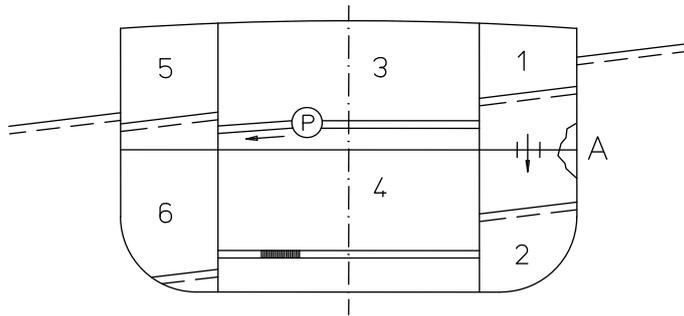
Type =3 represents pumping between two compartments. The data is stated in a similar way as above but *zA* is replaced with pumping capacity (volume/sec). The pumping is made from compartment n1 to n2.

N.B: It is not allowed to state negative pumping capacity to obtain pumping from n2 to n1.

Pumping stops when opening I comes above the liquid level in compartment n1 and when compartment n2 is full The program checks these items in each calculation step and pumping starts immediately after changing in the mentioned restrictions.

Example:

Data stated on the enclosed data sheet corresponds in principal to the sketch shown below.



Compartment 1 and 2 are opened by the damage at A. Since two compartments are involved, the damage has to be divided and described as one damage for compartment 1 and one for compartment 2. Except this damage we have an opening between room 1 and 2. Between room 1 and 3 there is the watertight door which is assumed to be open the first two minutes after damage. P defines a pump pumping from room 1 to 5 and finally there is a cross connection between room 2 and 6.

Compartments can also contain liquids at the starting time $t = 0$ (for example FW or Fuel Oil). In fact the program calculates also the successive changes in density for such compartments caused by flooding and pumping. The liquids are specified on data sheet 9.

Summary

The program as described here can in detail calculate the process of almost any type of flooding in a ship. Calculation of complete GZ curves are made for stipulated time intervals.

Example of use of the program are:

- Calculation of the time period between the damage and the sinking
- Damage stability calculations for progressive flooding
- Calculation of the function of cross-filling connections
- Calculation of stability at fire when
 - a) water is pumped on various decks
 - b) down-flow through openings takes place
 - c) outflow and pumping out of water from various compartments
 - d) a number of free surfaces on various decks occur

Damage stability

54	ship no	nl	ns	fproc	method	flooding stage factor	spec			
55	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
56	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10

nl number of loading cases
 ns no of damage cases
 fproc =0 normally
 fproc =0 flooded volume is kept constant at heeling for intermediate flooding
 fproc =1 flooding volume is varying with the angle of heel also for the intermediate flooding
 meth =blank (normally) righting arms and trans. metacentre related to displ. before damage
 meth =1 righting arms and trans. metacentre related to displ. incl. flooded water
 flooding stage given here or on data sheet 10
 factor
 spec =0 (this trigger is used for indication of special versions of the program)
 (or blank)

normally blank

Reference points and openings

57	frame no	dx	y	z	type
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				
	21				
	22				
	23				
	24				
	25				
	26				
	27				
	28				
	29				
	30				
	31				
32					
one blank line					

Printing of intermediate results

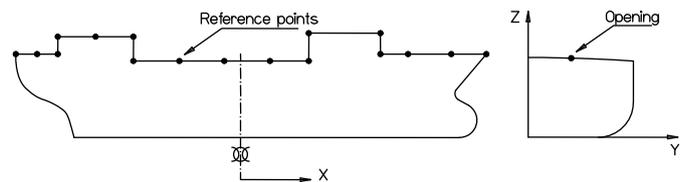
p1 =1 print heeling moment for each compart. containing liquid
 p2 =1 print details for each flooding calculation

Control of printout

r1 =1 omit printing of input data
 r2 =1 omit pecked in result
 r3 =1 sin-cos lines in result
 r4 =1 displ-lines in result
 r5 =1 draft-trim lines and flood stage no in result
 r6 =1 position of reference points after the damage
 r6 =2 print shortened data for reference points
 r7 =1 omit loading cond. in result
 r7 =2 omit shortened loading cond.
 r8 =1 omit damages specification
 r8 =2 print shortened damaged specification
 r9 =1 omit printing criteria evaluation
 r9 =2 print shortened data for criteria evaluation
 r9 =3 print with explaining comments for criteria evaluation

Type

1 Reference points (margin line)
 2 Openings



Punch sequence of damage stability data:

1. sheet 8
2. sheet 8a
3. required no of sheet 9
4. required no of sheet 10

Loading conditions

	loading case no	description text of the loading case
61		

	loading condition before the damage					
	ρ	d	t	CCG	KG	n
62	1			0.		
	ρ	D	t	CCG	KG	n
62	2			0.		
	ρ	D	LCG	CCG	KG	n
62	3			0.		

Description of symbols:

- ρ density of the sea water (ton/m³, or ton/cubft)
- D displacement
- d draft moulded
- t trim
- LCG longitudinal centre of gravity
- CCG centre of gravity from CL (pos. to SB)
- KG centre of gravity above BL
- n = no of comp with specified fluid cargo, ≤ 50

compartments with fluid cargo			
comp no.	weight of cargo	density	% filling
63 1			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28	one blank line		

If KG is known and given above, a calculation for this KG value is done, results printed and the criteria from data sheet 8 are used to check whether the loading condition meets the set requirement.

If the KG is unknown, leave it blank. The least permissible metacentric height is calculated and all curves of stability are calculated for this limiting metacentric height.

Curves of stability are corrected for free surface effects arising from fluids contained in each specified compartment.

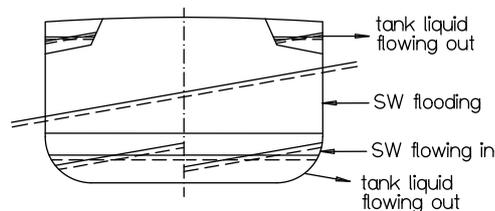
Fluid cargo can be defined as follows:

1. weight and density are stated (% filling is calculated)
2. weight and % filling are stated (density is calculated)
3. weight, density and % filling are stated. The % is used only to calculate the centre of gravity and moment of inertia

Damage on SB side

The sketch demonstrates three different effects which are all correctly treated by the program:

1. Heeling moment from moving liquids (portside)
2. Tank liquid flowing out and SW flowing in
3. Tank liquid flowing out



N.B.

Permeability for compartments with fluid cargo (specified on this sheet) must be given on sheet 7 and not on sheet dm3.

5.3.3 Execution procedure for damage stability in real time

- HULL74 data sheets 1 to 4
- STHYD data sheet 5:1
- STABB
- VOL1 data sheets 6, 7
- VOL2
- VOLLC data card as follows: 3 0 1
- DAM1R data sheet 8, 9 10R
- DAM2R
- DAM3P one blank card

To decrease output, blank card can be replaced with the card containing ip1, ip2, ip3 and ip4 as follows:

ip1 =0 no action
ip1 =1 omit printing of displacement, draft, trim and angle
ip2 =0 no action
ip2 =1 omit printing of GZ curves
ip3 =0 no action
ip3 =1 omit printing of volumes and levels in compartments
ip4 =0 no action
ip4 =1 omit printing of flooding through openings
iall =0 normally, results from all time steps are printed
iall =i > 1 result from each i-th time step printed

5.3.4 Theory and calculation method for damage stability program in real time

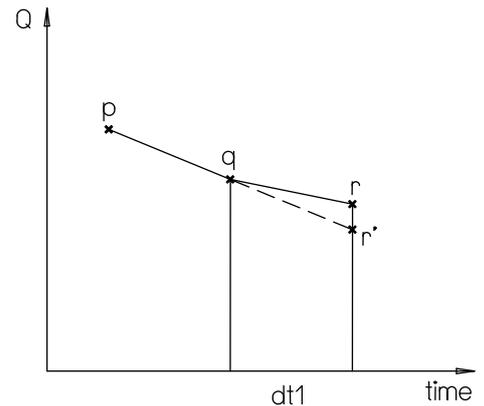
The basic method for the program is to calculate flooding step by step using small time intervals. For each step the new levels for the liquid are calculated. The influence of draft, trim and heel on the levels are taken into account. From the new levels, new flooding speeds are calculated. Enclosed “The formulas for flow” are the basis for the chosen method. It shows that the flow changes linearly (as a function of the time) under some conditions which in most cases are met or nearly met.

Calculation procedure

1. Main principal

1.1 Extrapolation

- From the two preceding calculated values of speed Q_p and Q_q a new value $Q_{r'}$ is extrapolated
- The flow during dt_1 is now $0.5 \cdot (Q_q + Q_{r'}) \cdot dt_1$ according to “The formulas for flow”.
- The new volumes, levels in each compartment, draft, trim and heeling angle are now calculated.



1.2 Calculation

- In this new position the speed Q_r is calculated.
- The total flow from all openings is calculated.

1.3 Comparison

The difference between calculated and extrapolated flow is calculated. Three different cases might occur:

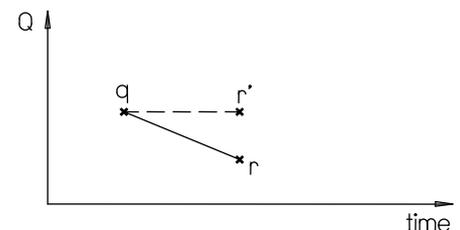
- The difference is very small as well as the change in draft, trim and heel. The calculated time step is accepted. Next time step is increased.
- The difference is acceptable as well as the change in draft, trim and heel. The calculated time step is accepted. Next time step = previous time step.
- The difference is too large and/or the change in draft, trim and heel is too big. The result of the time step is not accepted. The time step is decreased and the previous calculation is remade. If the min time step is already reached, see “The special treatment”

The differences are deemed very small, acceptable or too big based on the control data given in input data sheets 10R data set 91.

2. Special treatments

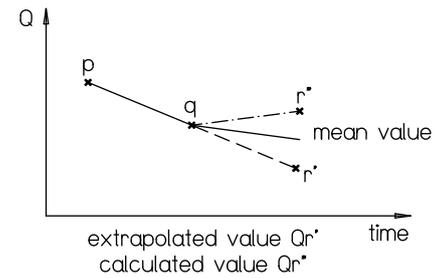
2.1 First time step or a new action starts

- For the actual position calculate the speed Q_q .
- As it is not possible to extrapolate now the extrapolated value is set = the calculated value $Q_{r'} = Q_q$.
- Continue with 1. 1.1 b)



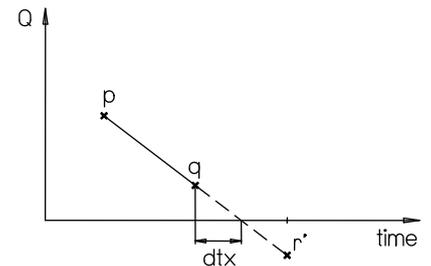
2.2 Min time step and the differences are still not accepted

- If the difference is too big and min time step is reached, a new try is made with the mean value of $Q_{r'}$ and $Q_{r''}$.
- Continue with 1. 1.1 b)
- This is repeated until the difference is accepted or max 4 times. In the last case a warning is written and the program continues with the next time step.



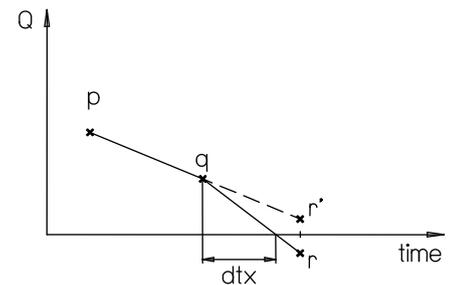
2.3 Change of direction in flow at extrapolation

- If Q_q and $Q_{r'}$ have different direction, the time step is decreased to dt_x so that $Q_{r'} = 0$.
- Continue with the 1. 1.1 b)



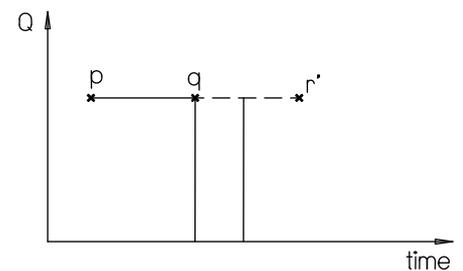
2.4 Change of direction in flow at calculation

- If Q_q and Q_r have different direction the transferred liquid = flow during the time dt_x the time step is not changed
- Continue with the 1. 1.1 b)



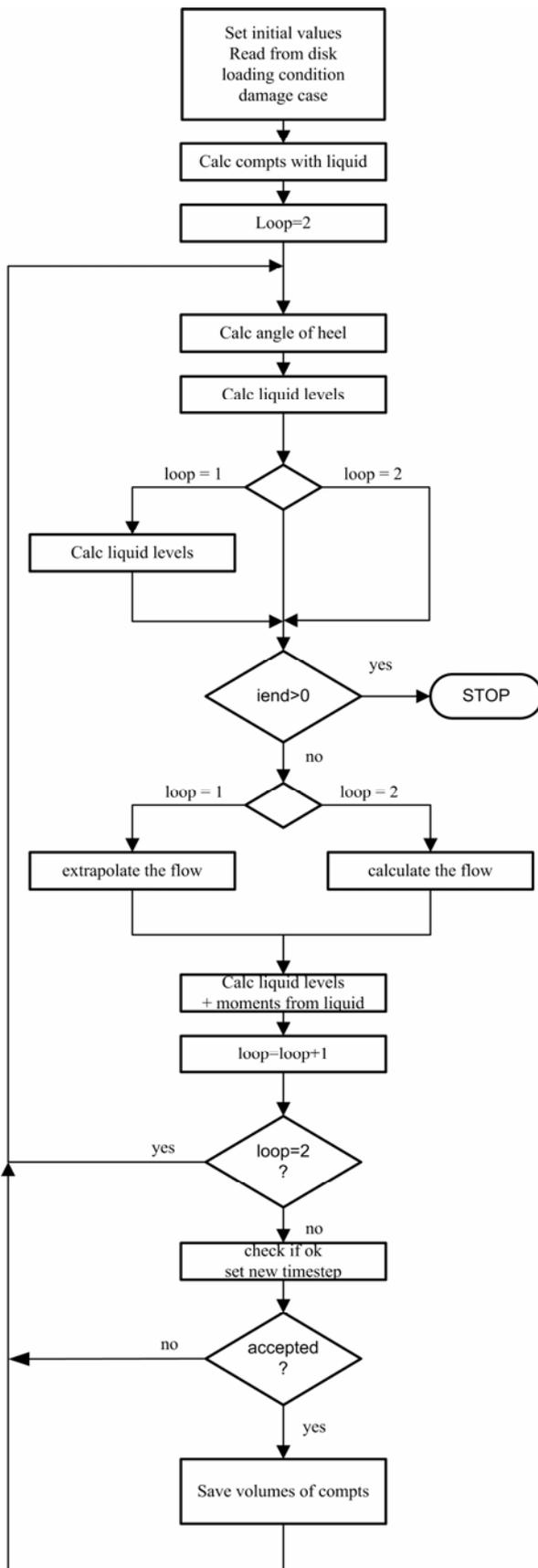
2.5 Discontinuity because of one compartment becomes empty or full during the time step

- If a compartment becomes empty resp. full during the time step, the amount of transferred liquid is reduced so that it corresponds to an empty resp. full compartment.
- Continue with the 1. 1.1 b) if extrapolation loop otherwise with 1. 1.2 b)

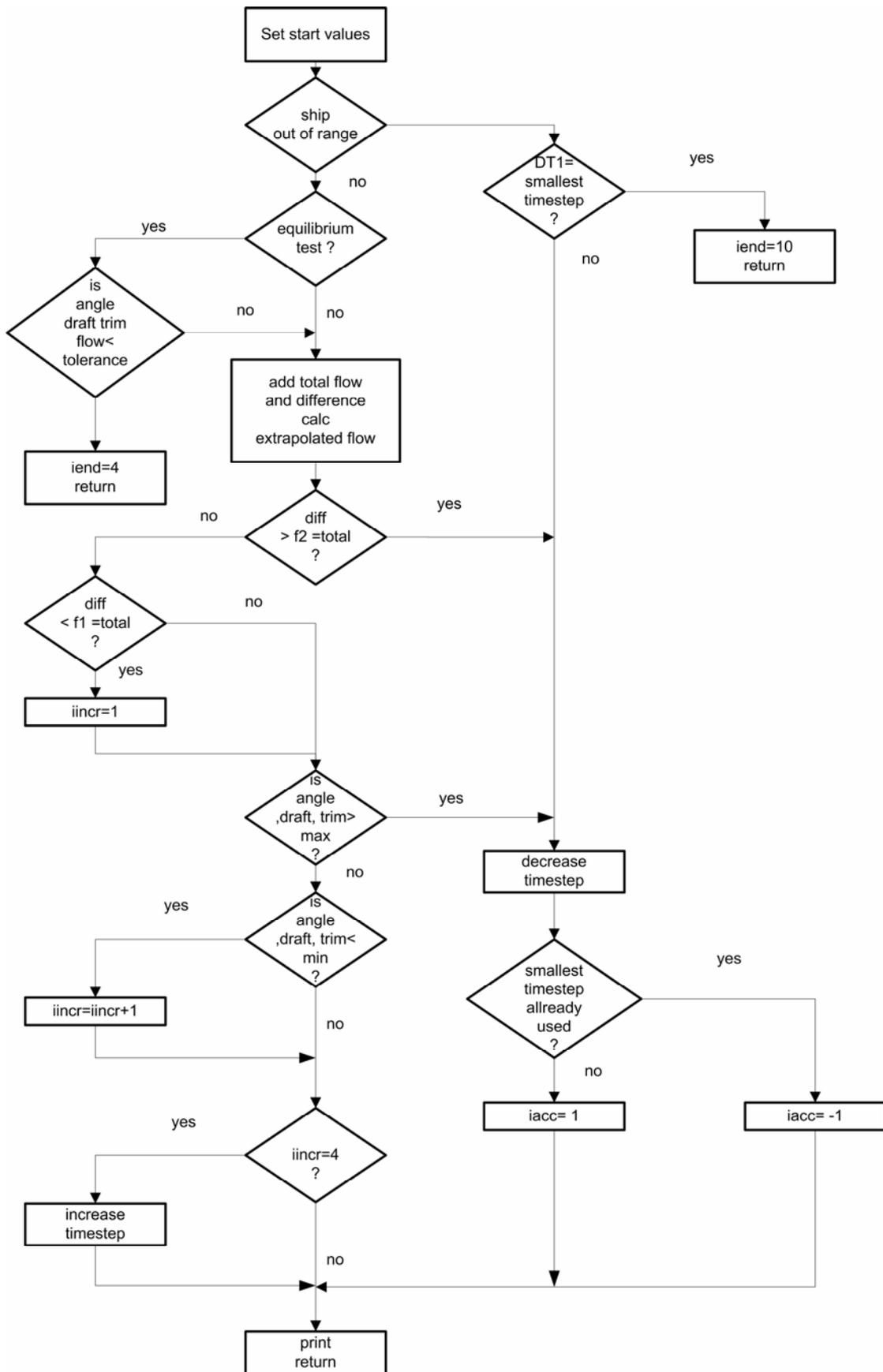


The following flow charts “Dflow” and “Heang” show the control of the time step resp. the calculation of heeling angle.

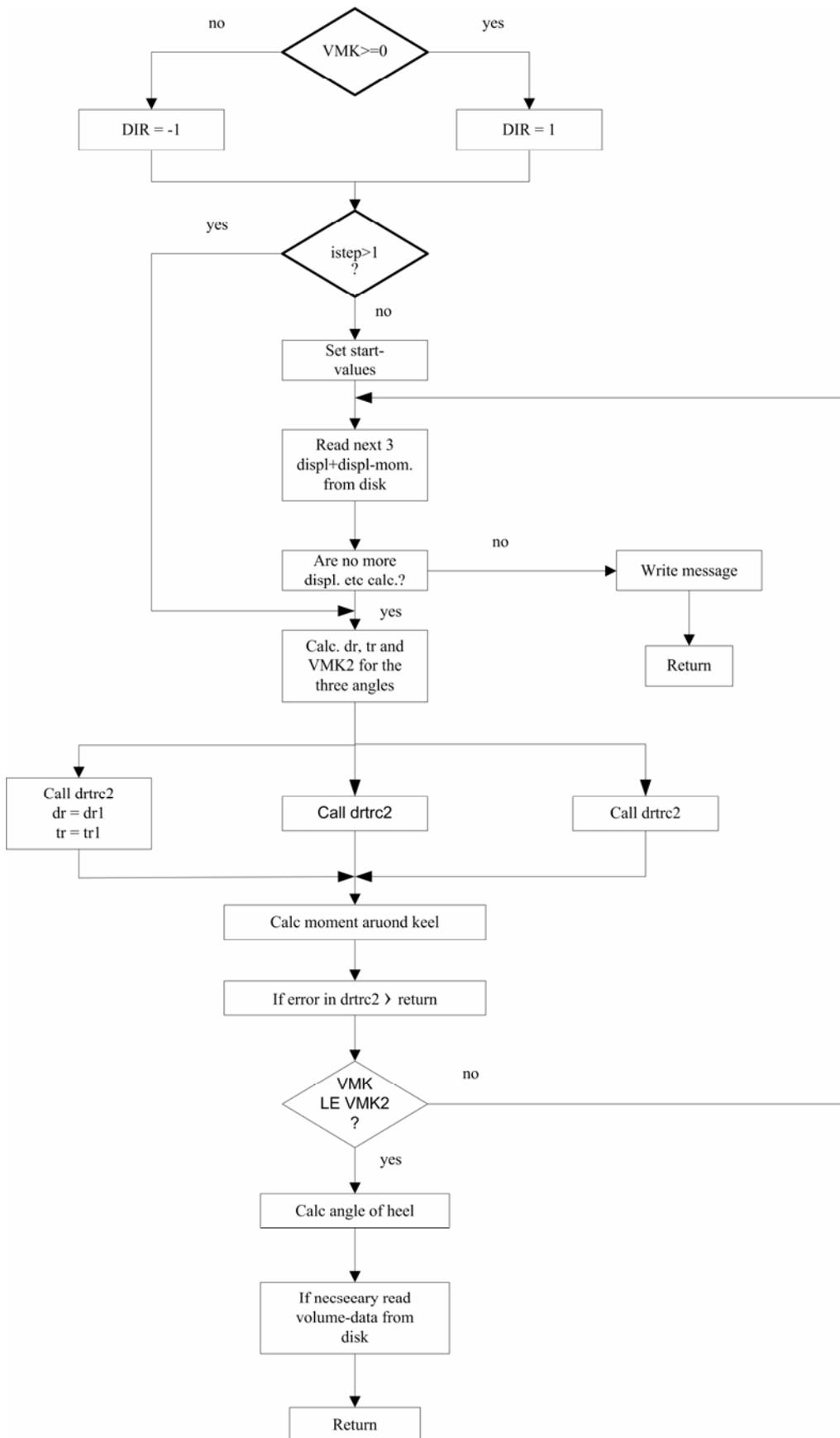
Flowchart DAM2R



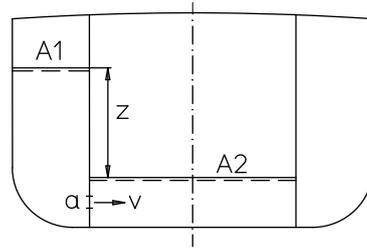
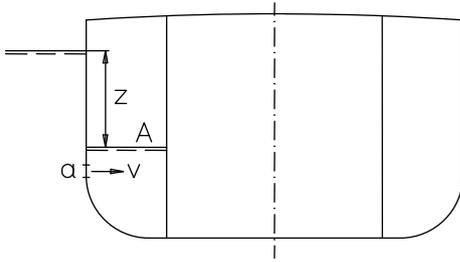
Flowchart DFLOW



Subroutine "HEANG"



Formulas for flow



$$dz = \frac{dV}{A1} + \frac{dV}{A2} \text{ equivalent to outflow with area}$$

$$A \frac{1}{A} = \frac{1}{A1} + \frac{1}{A2}$$

$$1. \quad dV = A * dz = -a * \sqrt{2 * g * z} * dt$$

$$\frac{dz}{\sqrt{z}} = \frac{a}{A} * \sqrt{2 * g} * dt$$

$$2. \quad 2 * (\sqrt{z1} - \sqrt{z2}) = \frac{a}{A} * \sqrt{2 * g} * (t2 - t1)$$

v_m = the mean speed during period $t1 - t2$

$$v_m = \frac{(z2 - z1) * A}{a * (t2 - t1)} - \text{insert the } t2 - t1 \text{ from above}$$

$$3. \quad v_m = \frac{(z2 - z1) * A}{a} * \frac{a}{A} * \frac{\sqrt{2 * g}}{2} * \frac{1}{\sqrt{z1} - \sqrt{z2}} = \frac{\sqrt{2 * g * z1} - \sqrt{2 * g * z2}}{2}$$

This is a useful fact that the true mean value of the speed (v_m) at outflow is identical with the arithmetic mean value of the speed at the start ($\sqrt{2 * g * z1}$) and at the end ($\sqrt{2 * g * z2}$) of the period in question. In the program the speed at time $t = t1$ is calculated.

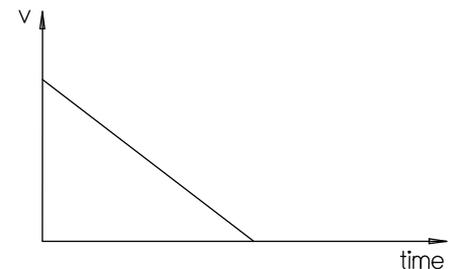
Relation between speed and time from 2.:

$$\sqrt{2 * g * z1} - \sqrt{2 * g * z2} = \frac{a}{A} * g * (t2 - t1)$$

$$v1 - v2 = \frac{a}{A} * g * (t2 - t1)$$

$$\frac{dv}{dt} = -\frac{a}{A} * g$$

Formula 3. for mean speed v_m is obvious from the figure.



Extrapolation

Linear extrapolation of v is therefore a good approximation even when the conditions above are not exactly met.

Let take $p - q$ and $q - r$ as two consecutive calculation steps.

For interval $p - q$ flooded volume:

$$Q = \frac{(V_p - V_q)}{2} * (t_q - t_p) * \mu * a$$

but for interval $q - r$

$$Q = \frac{V_q}{2} * (t_r - t_q) * \frac{V_q}{V_q - V_r} * \mu * a$$

where v_r is the extrapolated neg. speed value.

After calculation of Q , v_r is set =0 and no more flow takes place.

