8 Launching and docking

Few who have witnessed the launch of a vessel will have failed to experience the awesome nature of the event. The naval architect is responsible for the safe movement from land to water for the first time of vessels sometimes of thousands of tonnes. Predictions of the movement are vital to its safe control. The reverse procedure, of bringing a ship into dock also requires some sound practical knowledge assisted by theory.

Launching

A ship is best built under cover for protection from the elements leading to better quality and less disruption of schedules. Because of the capital costs it was not until the 1970s that covered slipways became fairly common. Partly to offset these costs a conveyor belt method of construction was pioneered in Scandinavia. The ship is built section by section and gradually pushed from the building hall into the open. A dry dock can be used and flooded up when the ship is sufficiently far advanced. A dry dock is too valuable a capital asset to be so long engaged and the method is generally confined to very large vessels where normal launching presents special difficulties. Occasionally, slipways are partially or wholly below high water level and the site is kept dry by doors which, on launch day are opened to let the water in and provide some buoyancy to the hull. More often, the hull is constructed wholly above water and slid into the water when ready. Very small hulls may be built on a cradle which is lowered on wheels down a ramp into the water, but ships over about 100 tonnef displacement must be slid on greased ways under the action of gravity.

Usually, the ship slides stern first into the water because this part of the ship is more buoyant, but bow first launches are not unknown. The theory presently described is applicable to both. Less often, the ship is slid or tipped sideways into the water and the considerations are then rather different.

In a well ordered, stern first launch, sliding ways are built around the ship, and shortly before the launch the gap separating them from the fixed groundways is filled by a layer of grease to which the weight of the ship is transferred from the building blocks.

There may be one, two or even four ways; generally, there are two although in Holland one way with propping ways at the sides are common. The ways are inclined and, often, cambered. Movement is prevented until the desired moment by triggers which are then knocked away to allow the ship to move under gravity down the inclined ways. After it begins to enter the water, buoyancy builds up at the stern until it reaches a value sufficient to pivot the entire ship about the fore poppet (i.e. the forward end of the launching cradle). The ship continues down the ways until it is floating freely having slid away from, or dropped off the end of, the ways. If launched in a restricted waterway, its progress into the water is impeded by drags which are arranged so as gradually to bring the vessel to a stop before it strikes the far bank.

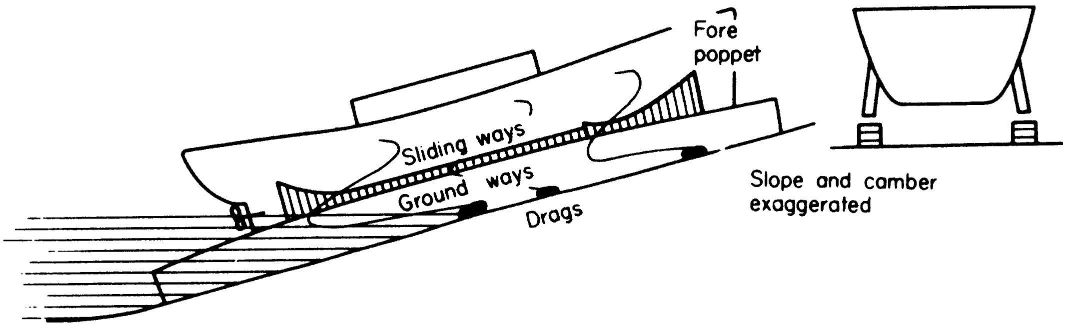

Fig. 8.1 A stern first launch

Consider what might go wrong with this procedure. The grease might be too slippery or not slippery enough. It might be squeezed out by the pressure. Instead of the stern lifting, the ship might tip the wrong way about the end of the groundways and plunge. The forefoot might be damaged by dropping off the end of the ways or it may dig into the slip when the stern has lifted. The ship might be insufficiently strong locally or longitudinally or the ways may collapse. The breaking effect of the drags might be too much or too little. The ship might, at some instant, be unstable.

Calculations are carried out before arranging the launch to investigate each one of these anxieties. The calculations predict the behaviour of the ship during launch, to enable a suitable high tide to be selected and to arrange the ship and slip to be in a proper and safe condition.

LAUNCHING CURVES

A set of six curves is prepared to predict the behaviour of the ship during launch. They are curves, plotted against distance of travel down the slip, of

(i) Weight, W
(ii) Buoyancy, Δ
(iii) Moment of weight about fore poppet, Wa
(iv) Moment of buoyancy about fore poppet, Δd
(v) Moment of weight about after end of groundways, Wb
(vi) Moment of buoyancy about after end of groundways, Δc

The geometry of the ship at any position in its travel down the ways is illustrated in Fig. 8.2 for the ways in contact. A distributed load $(W - \Delta)$ along the ways is not shown; after the stern lifts this becomes concentrated all at the fore poppet. Conventionally, the moment (v) is drawn positive when anti-clockwise and (vi) is drawn positive when clockwise. A typical set of launching curves is shown in Fig. 8.3.

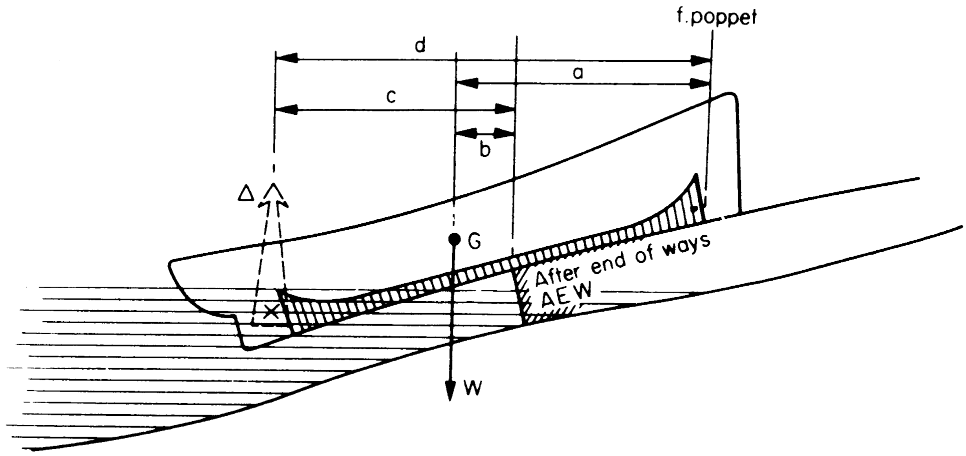

Fig. 8.2 Ship and way geometry

The important features of these curves are as follows:

(*a*) at the point at which the moment of buoyancy about the fore poppet equals the moment of weight about the fore poppet, the stern lifts;
(*b*) the difference between the weight and buoyancy curves at the position of stern lift, is the maximum force on the fore poppet;
(*c*) the curve of moment of buoyancy about the after end of the ways must lie wholly above the curve of moment of weight; the least distance between the two curves of moment about the after end of ways, gives the least moment against tipping about the end of ways;
(*d*) crossing of the weight and buoyancy curves before the after end of ways, indicates that the fore poppet will not drop off the end of the ways.

These curves answer some of the anxieties about the launch directly, but certain other investigations are necessary. From the difference between the weight and

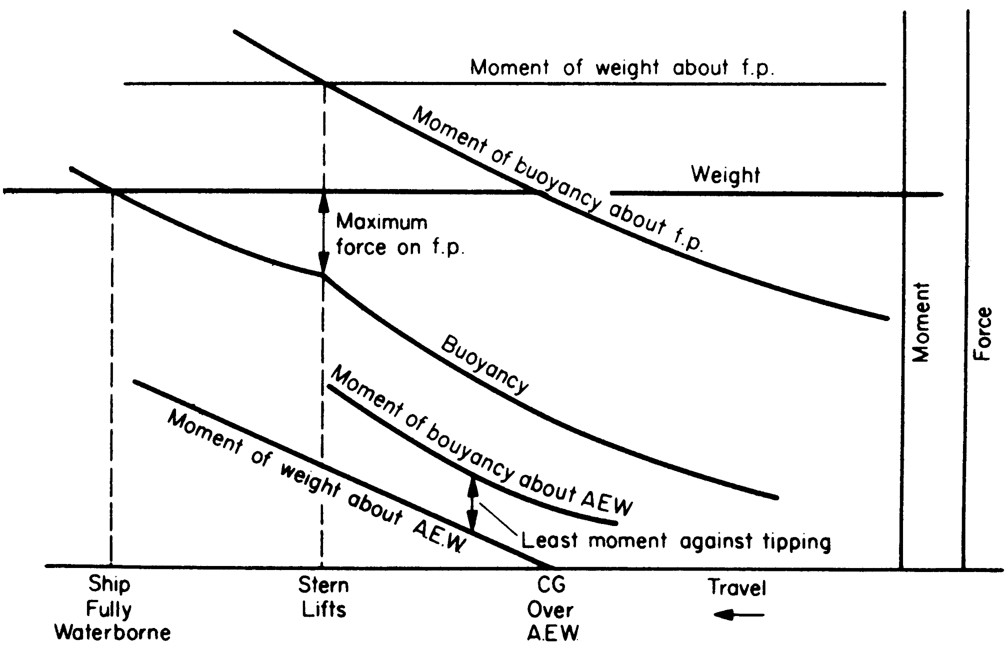

Fig. 8.3 Typical launching curves

buoyancy curves before stern lift, the grease pressures can be determined. This difference at stern lift (and for large vessels, it could well exceed 10,000 tonnef) giving the maximum force on the fore poppet, enables the poppet and internal strengthening of the ship to be devised; it also causes a loss of stability. From all of these features is judged the adequacy of the height of tide and the length of ways. Indeed, curves are usually constructed for more than one height of water to determine the minimum acceptable height. How are the curves constructed?

CONSTRUCTION OF LAUNCHING CURVES

The curve of weight results usually from the weights weighted into the ship plus an estimate of what remains to be built in during the period between calculation and launch. Centre of gravity position is similarly estimated and the two moment of weight curves produced.

Buoyancy and centre of buoyancy at any position of travel is determined by placing the relevant waterline over a profile of the ship with Bonjean curves drawn on and integrating in the usual fashion. For this calculation, dynamic considerations are ignored and the ship is assumed to travel very slowly. While the correct waterline can be determined by sliding a tracing of the ship over a drawing of the slip, it is more accurately found from the geometry of the situation. Let

$\alpha =$ the initial slope of the keel
$L =$ length between perpendiculars
$e =$ distance of the fore poppet abaft the FP
$h =$ initial height of the fore poppet above water
$\beta =$ declivity of groundways, i.e. slope of chord
$f =$ camber of ways of length K
$r =$ radius of camber
$t =$ distance abaft the fore poppet

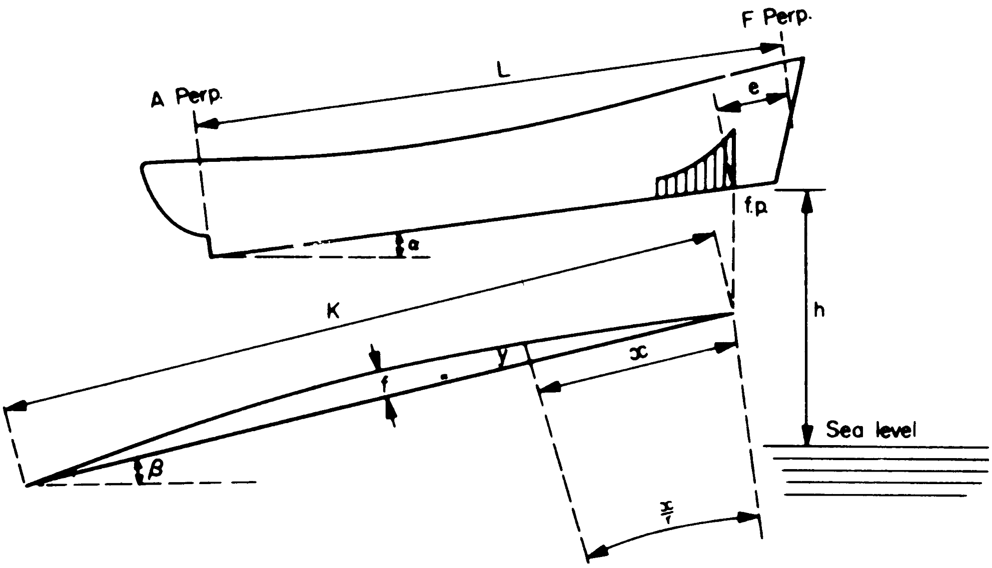

Fig. 8.4

From simple mensuration, the camber of an arc of a circle is given by

$$f = \frac{K^2}{8r} \quad \text{so that} \quad (f - y) = \frac{(K - 2x)^2}{8r}$$

$$\therefore\ y = \frac{K^2}{8r} - \frac{(K - 2x)^2}{8r} = x\frac{(K - x)}{2r}$$

After travelling a distance x, the fore poppet is raised y above the chord and the keel has moved through an angle x/r. The height of the fore poppet above the water is now therefore, approximately

$$h - \beta x + y = h - \beta x + \frac{x}{2r}(K - x),$$

while the height above water of a point t abaft the fore poppet is

$$h - \beta x + y - t\left(\alpha + \frac{x}{r}\right) = h - \beta x + \frac{x}{2r}(K - x) - t\left(\alpha + \frac{x}{r}\right)$$

If there is no camber, r is, of course, infinite.

If, in this expression t is put equal to $-e$, it will give the height of the keel at the FP above water or, when it is negative, below water, i.e. the draught at the FP. If t is put equal to $L - e$, the expression gives the negative draught at the AP. Thus, for a given travel down the ways x, a waterline can be drawn accurately on the Bonjean profile from which buoyancy and centre of buoyancy can be determined.

This is satisfactory when the ways are fully in contact, but after stern lift, while the draught at the fore poppet can be determined in this way, trim cannot. Now at all times after stern lift the moments of weight and buoyancy about the fore poppet must be equal. For the position of travel under consideration, the fore poppet draught is found as already described; buoyancy and moment of buoyancy are then calculated for several trims about the fore poppet and a curve plotted as shown in Fig. 8.5. Where the curves of moment about fore poppet cut, there is the correct trim; buoyancy can be read off and the position of centre of buoyancy calculated. Having determined the correct trim, the passage of the forefoot to assess the clearance from the slip can be drawn.

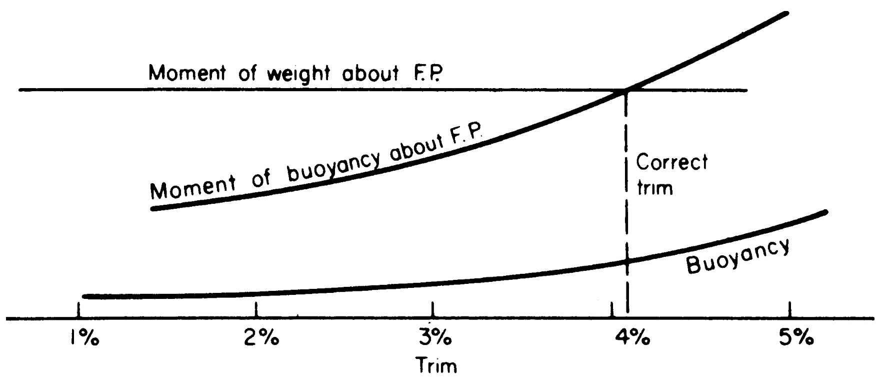

Fig. 8.5 Determination of correct trim after stern lift

If the launching curves indicate that the fore poppet will drop off the ways, adequate depth of water must be allowed under the forefoot for the momentum of the drop to prevent damage to the forefoot. What is adequate will depend on the amount of the excess of weight over buoyancy, the inertia of the ship and the damping effects of the water; it is best determined from an examination of previous launches.

GROUNDWAYS

Typically, the declivity of the groundways is 1 in 20 and the camber a half a metre in a groundway length of 300 m from fore poppet to after end. The radius corresponding to this camber is 22,500 m. Originally, camber was probably meant to offset the sinkage of the slip as the ship's weight grew. It has another important effect in rotating the ship to dip the stern deeply into the water; this increases the buoyancy force and causes an earlier stern lift than would be the case without camber. This increases the moment against tipping but also increases the load on the fore poppet.

The total load on the groundways is the difference between weight and buoyancy $W - \Delta$. Dividing by the length in contact gives a mean load per unit length and this, divided by the width of ways gives a mean pressure. The maximum total load on the ways is the initial one, W, and experience has shown that the mean pressure associated with this load should not, for many greases, exceed about 27 tonnef/m^2 or the grease tends to get squeezed out. Both the ship, which has an uneven weight distribution, and the ways are elastic and they are separated by grease; what is the true distribution of pressure along the length has never been measured. Ignoring the moment causing the small angular acceleration of the ship due to camber, it is known that, before stern lift (Fig. 8.2),

(*a*) $W - \Delta =$ total load on ways,
(*b*) $Wa - \Delta d =$ moment of way load about fore poppet.

Some appreciation of the load distribution at any instant can be obtained by assuming that the distribution is linear, i.e. that the curve of load per unit length p' against length is a trapezoid. If the length of ways remaining in contact is l at any instant and the loads per unit length at the fore poppet and after end of ways are, respectively, p'_f and p'_a, the conditions (*a*) and (*b*) become

(*a*) $W - \Delta = \frac{1}{2}l(p'_f + p'_a)$
(*b*) $Wa - \Delta d = p'_f\dfrac{l^2}{2} + \dfrac{1}{3}l^2(p'_a - p'_f)$

Solving these equations for p'_f and p'_a,

$$p'_f = 4\frac{W - \Delta}{l} - 6\frac{Wa - \Delta d}{l^2}$$

$$p'_a = 6\frac{Wa - \Delta d}{l^2} - 2\frac{W - \Delta}{l}$$

This is a satisfactory solution while p'_f and p'_a are positive, and the load per unit length can be represented by a trapezium. When $(Wa - \Delta d)/(W - \Delta)$ is greater than $\frac{2}{3}l$, p'_f becomes negative and when $(Wa - \Delta d)/(W - \Delta)$ is less than $\frac{1}{3}l$, p'_a becomes negative. There cannot be a negative load so for these conditions, the trapezoidal presumption is not permissible. It is assumed, instead, that the distribution is triangular whence, for

$$\frac{Wa - \Delta d}{W - \Delta} > \frac{2}{3}l \quad \text{then} \quad p'_a = \frac{2(W - \Delta)^2}{3l(W - \Delta) - 3(Wa - \Delta d)}$$

and for

$$\frac{Wa - \Delta d}{W - \Delta} < \frac{1}{3}l \quad \text{then} \quad p'_f = \frac{2(W - \Delta)^2}{3(Wa - \Delta d)}$$

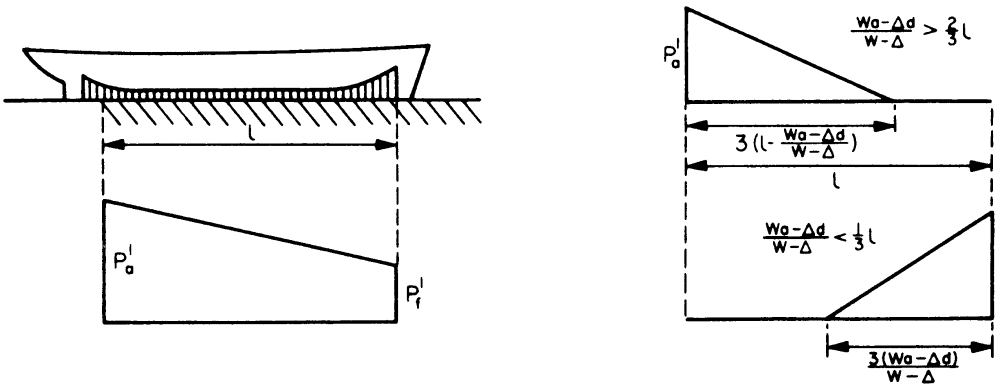

Fig. 8.6 Assumed load distribution

It is now possible to plot the maximum loads or pressures against travel down the slip (Fig. 8.7). Permissible grease pressures vary with grease, temperature and past experience. 55 tonnef/m^2 is typical but figures of 100 or 150 are not unknown. The calculation helps determine poppet strength and where internal shoring is needed.

Apart from the assumption of linear variation in pressure the above method of calculation assumes the ship and slipway to be rigid. It has been suggested

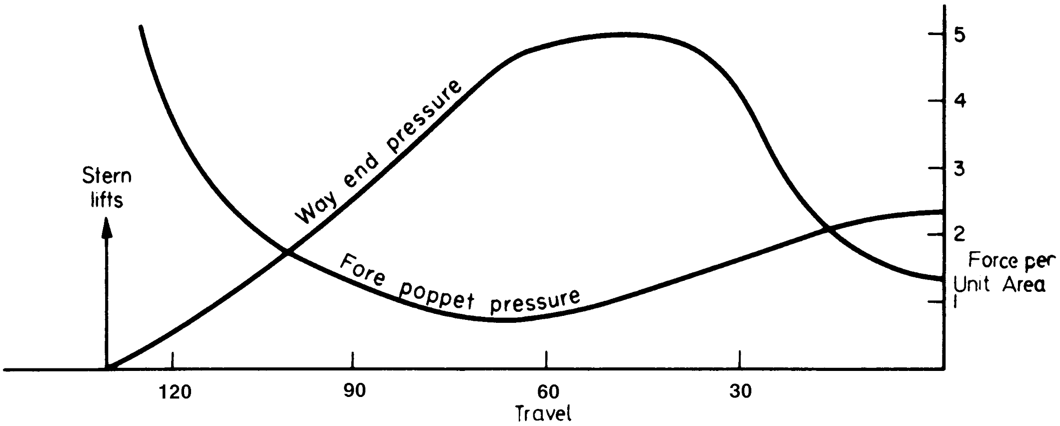

Fig. 8.7 End pressures

that the simple method predicts way end pressures which are unrealistically low and a more rigorous treatment allowing for ship elasticity, flexibility of the ways and the effects of bottom panel deflection may be wise. Pressures may be reduced by champfering the ends of the ways and may be physically limited by using deformable packing or collapsible cushions.

THE DYNAMICS OF LAUNCHING

The force accelerating the ship down the groundways is, at any instant, approximately

$$(W - \Delta)\theta - \text{way friction} - \text{water resistance} - \text{drag forces}$$

θ is the slope of the ways at the centre of gravity of the ship. Way friction is $\mu(W - \Delta)$; the coefficient of friction μ is usually less than 0.02, although at the commencement it can be slightly higher and tests should be conducted to establish the figures for the particular lubricant over a range of temperatures. Water resistance is due to the hull friction, the creation of the stern wave and to the resistance of locked propellers, water brakes or masks, etc., where fitted; this resistance is expressed by $K\Delta^{2/3}V^2$ where V is the velocity of travel and K is a constant determined from similar ships with similar water braking devices. Retarding forces due to chain drags are found to follow a frictional law, $\mu' w$ where w is the weight of the chains and μ' is 0.40–0.80 depending upon the state of the slipway; this figure must be determined from trials or from previous launches.

For a particular ship the effects of entrained water can be expressed as a fraction z of the buoyancy. The equation of motion of the ship before it is waterborne is then

$$(W - \Delta)\theta - \mu(W - \Delta) - K\Delta^{\frac{2}{3}}\, V^2 - \mu' w = \text{net force} = \frac{(W + z\Delta)}{g}\frac{\mathrm{d}V}{\mathrm{d}t}$$

This differential equation cannot, of course, be solved mathematically because of the presence of Δ.

Consideration of each of the factors at intervals of travel down the slip, however, enables a component force diagram to be built up as shown in Fig. 8.8 and a distance–time relationship estimated from it, by equating the nett force to the mass $\times$ acceleration. After the ship has become waterborne, the first two components of the expression become zero. Integration of each component force–distance curve gives the work done in overcoming that resistance. Velocity at any point of travel may therefore be checked by relating the kinetic energy at that point to the loss of potential energy minus work done in overcoming friction and resistance.

STRENGTH AND STABILITY

Problems of local strength occur at the keel over the after end of the ways and at the fore poppet both for the ship and for the poppet structure. The difficulties of containing the large forces at the fore poppet account for the increasing

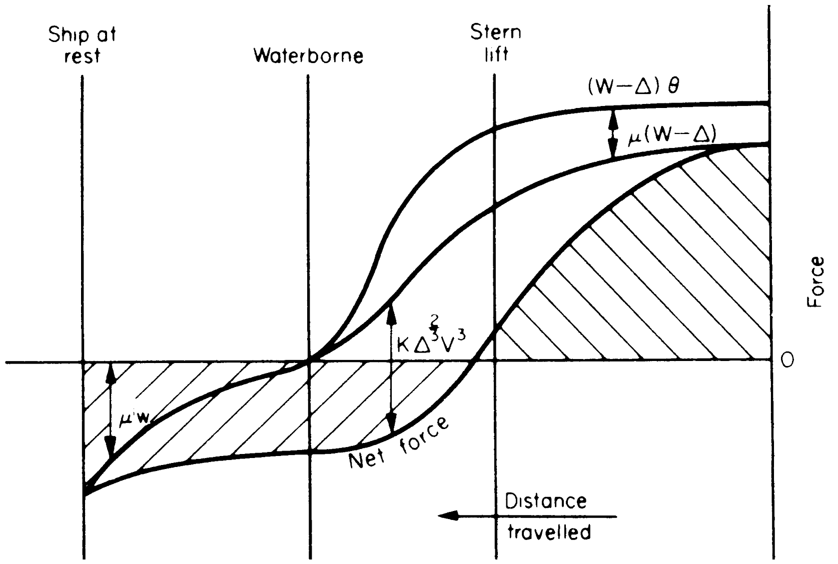

Fig. 8.8 Forces acting during launch

number of very large oil tankers and other bulk carriers being built in dry docks (productivity is of course high).

At the instant of stern lift, the hull girder undergoes a maximum sagging bending moment, the longitudinal strain from which in some large ships has been measured to give stresses of 90 MN/m^2. The bending strain is easily found from the data already compiled to ensure a safe launch but strain measured in practice is usually somewhat below this, due probably to the effects of water resistance. Breakage, that is the longitudinal bending of the ship, is usually measured.

Stability is also at a minimum at the instant of stern lift due to the large fore poppet load at the keel. The $\overline{GM}$ is calculated by the methods described in Chapter 5 both for the ship with the concentrated load at the keel and fully afloat. While instability with the ship supported each side by the ways is unlikely, no naval architect would permit a ship to be launched with a negative virtual $\overline{GM}$ at the instant of stern lift. Any sudden sinking of the ways, for example, could be increased by an unstable ship. Ballasting is, in any case, often carried out to increase the longitudinal moment against tipping and presents no difficulty if needed for stability purposes.

SIDEWAYS LAUNCHING

When the ship is small or waterfront space is not at a great premium, ships may be built on an even keel broadside on to the water and consigned to the water sideways. There are three common methods of sideways launching:

(*a*) the ship slides down ways which are built well down under the water;
(*b*) the ship tips or drops off the end of the ways into the water, sometimes tipping a part of the ways too;
(*c*) the ship is built on piles which are made to collapse by a sideways push to allow the ship to fall into the water.

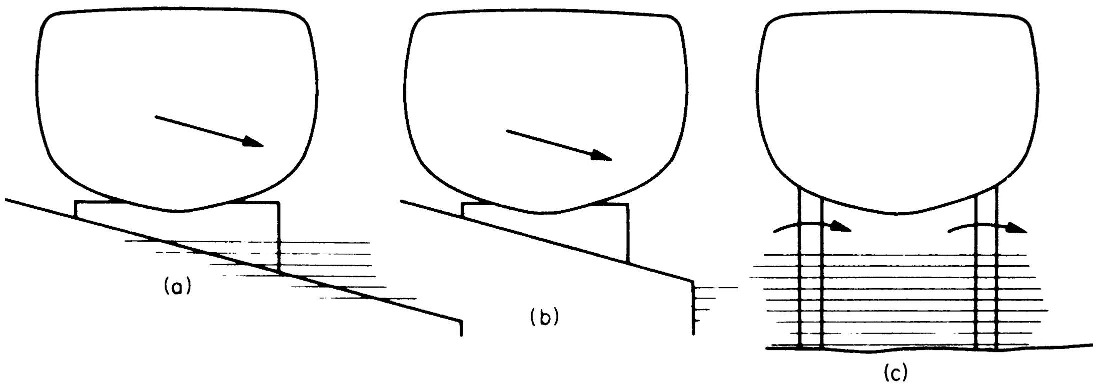

Fig. 8.9 Sideways launching

In all of these methods the ship takes to the water violently and may roll heavily—on entry, the ship may roll thirty degrees or more. Stability at large angles and watertightness are therefore important considerations. Waves may cause damage on adjacent shores.

Conventional calculations are not performed. Declivity of ways is usually of the order of 1 in 8 in order to give a high speed of launch to clear the end of the ways. Grease pressures permitted, 0.25 to 0.30 MN/m^2, are somewhat higher than with end launch.

Docking

From time to time, attention is needed to the outer bottom of a ship either for regular maintenance or to effect repairs. Access to the bottom may be obtained by careening, by hauling up a slipway or by placing in a dock from which the water is removed. There are limitations to what work can be done by careening, while the magnitude of the machinery needed to haul a ship up a slipway is such that this procedure is confined to ships up to a few hundred tonnef in displacement.

It has become common practice in some countries to build large vessels totally in a drydock and to allow the water to enter when the hull is in a satisfactory state. This undocking procedure must be investigated in a manner similar to that for normal docking or undocking to ensure that forces at the keel do not cause instability to the ship or that they do not trip the blocks. These matters are investigated in advance while evidence that affairs are what they should be is rigorously observed during the procedure by the dockmaster. This chapter is concerned with theory which assists such successful operations and some design features of floating docks. Features of principal concern are

(*a*) load distribution between dock and ship;
(*b*) behaviour of blocks;
(*c*) strength of floating docks;
(*d*) stability.

This list by no means exhausts the problems associated with docking and constructing docks, which include design of caissons and pumping systems and the whole field of difficulties facing civil engineers in the construction of graving docks. It does, however, embrace the major concerns of the practising naval architect. Basically, docking is the placing of an elastic ship with an uneven weight distribution on to an elastic set of blocks supported in turn by an elastic floating dock or a relatively rigid graving dock. Blocks will not be of an even height and are subject to crush, creep and instability. In many aspects of ship design, the criteria of design are based on misuse or accident; with floating docks, there is little scope for permitting maloperation because if this were a major criterion of design, the lifting capacity of the dock would be unduly penalized.

LOAD DISTRIBUTION

Theoretical analyses are available to study the behaviour of a ship in a floating dock to produce with some rigour the longitudinal distribution of loading on the blocks. A simplified procedure has often been found adequate as follows.

It is assumed that the load distribution along the blocks follows the weight distribution of the ship except at the after cut up and at any other gap in the blocks. Forward of the after cut up, the weight distribution is assumed augmented by the weight abaft the cut up spread over a length equal to twice the length of the overhang, and distributed according to a parabolic law such that the moment of weight is the same as the moment of overhang about the cut up. If the weight and moment of the overhang about the cut up are respectively W and M, the augment in load per unit length at the cut up, a, is

$$a = \frac{9W^2}{16M}$$

Fig. 8.10 Load distribution in dock

In a floating dock, the load distribution is further affected by the buoyancy distribution along the dock which is under the control of the dockmaster. For a given buoyancy distribution, the loading in the past has been determined by a method similar to the longitudinal strength calculation for a ship. The difference between the total buoyancy and ship's weight plus weight of dock and contained water gives the net loading. As explained in Chapter 6, shearing force on a girder is obtained by integrating the net loading, and bending moment is obtained by integrating the shearing force along the length. In the case of the docked ship, the loading and the subsequent integrations apply to the combined ship and dock. Difficulty arises in trying to separate the two because their interaction is not known. In the past, bending moment has been divided up in the ratio of their respective second moments of area of section. This is not satisfactory and comprehensive analysis is needed.

Floating docks are classified by their lifting capacity. Lifting capacity is the buoyancy available when the dock is floating at its working freeboard. Working freeboard is often 0.15 m at the pontoon deck. Buoyancy available arises from the tanks which can be emptied to provide lift to the dock without undue strain.

BLOCK BEHAVIOUR

Depending as it does on defects, age, grain, moisture content and surface condition, it is not surprising to find wide variation in the behaviour of a stack of wooden dock blocks, as experiments have shown. Provided that the blocks are cribbed to prevent instability, it is common practice not to permit block pressures in excess of 440 tonnef/m^2, although the ultimate load intensity of a stack of English oak blocks may be as high as 1090 tonnef/m^2.

Experiments have shown that the crippling pressure for a stack of blocks h high and a in width is given approximately by

$$p = 11\left(40 - \frac{h^2}{a^2}\right)\text{tonnef/m}^2 = 1.07\left(40 - \frac{h^2}{a^2}\right) \times 10^5\ \text{N/m}^2$$

where p is the load divided by the total plan area of a stack of blocks, irrespective of the half siding of keel. The formula is suitable for English oak and is obviously an approximation. A 2 m stack of 40 cm blocks has a crippling load of 165 tonnef/m^2. In practice, 2 m stacks are rare and pressures in excess of 220 tonnef/m^2 for a single uncribbed stack are not permitted. It is normal good practice to crib a certain number of blocks, which increases the crippling load as well as preventing tripping due to the trim of the docking ships.

The importance of exact alignment of blocks cannot be over-emphasized. Measurements of the loads in dock blocks have shown that a stack will take many times the load of its neighbour by being only a little higher. A lack of fit of 12 mm between adjacent blocks is not unusual at present and is responsible for wild variation in dock block loading. It is responsible, too, for the departures of the block loading curve from the ship's weight distribution in graving docks.

Great care is needed to ensure that blocks are all of even stiffness. The number of blocks to ensure a mean deflection of stacks of x is

$$\text{Number of blocks} = \frac{2 \times \text{ship's weight}}{x \times \text{block stiffness}}$$

For a mean deflection of 1 cm on blocks with a stiffness of 20 tonnef/cm, the minimum number of blocks required is $W/10$ tonnef. Clearly, this limitation is impractical for ships over about 2000 tonnef in displacement and, in general, the larger the ship, the closer the blocks are together and side blocks introduced.

STRENGTH OF FLOATING DOCKS

It is clear even from a cursory examination, that a dockmaster can place severe strains on a dock by a thoughtless selection of buoyancy tanks. In the transverse direction, if the dockmaster first selects the buoyancy tanks in the dock walls to begin raising the dock, a couple will be applied to the dock as shown in Fig. 8.11 which could cause damage. Similarly, in the longitudinal direction, if a ship has much weight amidships, the use of the buoyancy tanks at the ends of the dock could break it in two. It is good practice to select those buoyancy tanks immediately beneath the heaviest weights. Dock behaviour longitudinally, if the dock is made of steel, is checked continuously during lift by measuring the breakage. A strict limit to breakage is placed by the naval architect in the instructions for use of the dock. Reinforced concrete docks do not suffer much elastic distortion and breakage is not used as a measure of behaviour; instead, strict pumping patterns are imposed.

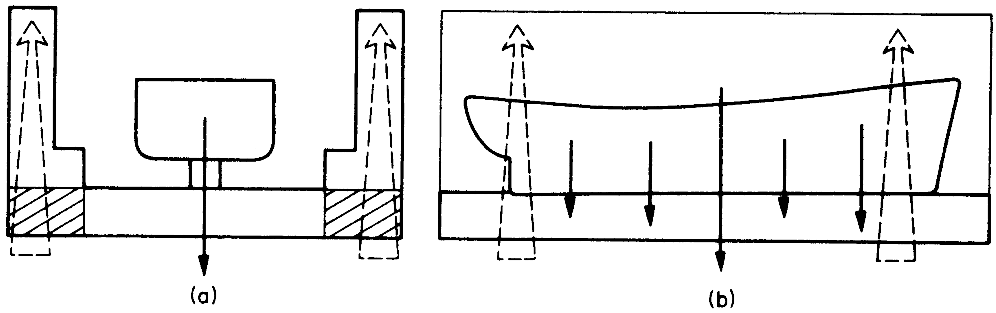

Fig. 8.11 Strains imposed by maloperation

Analysis of the strength of a floating dock was too difficult before computers had been satisfactorily programmed. Analyses now treat the dock bottom as a grillage simply supported at its edges by the two dock walls. The lumped weights of the docked vehicle are assumed supported by three rows of blocks constituted of stacks with a declared lack of fit. The problem is then analysed as an unevenly loaded beam on an elastic foundation for which programs are available.

The solution is equally applicable to graving docks by applying very high figures to the dock rigidity. Standard comparative longitudinal strength calculations to cater for transit conditions are also performed on the floating dock structure itself as described for the ship in Chapter 6.

The conventional floating dock is capable of taking very large vessels. A concrete floating dock may be capable of lifting a 350,000 dwt ship and a steel one of 400,000 dwt capacity.

STABILITY DURING DOCKING

Loss of stability due to grounding or docking has been discussed fully in Chapter 5. Calculation of this loss is a standard procedure before every docking, since a list developing before the ship is in contact with the blocks completely along the keel can be extremely dangerous and can dislodge the blocks.

A floating dock is trimmed approximately to the trim of the ship and large suing forces before the keel takes the blocks are thereby avoided. There is a critical stability condition when the ship is just clear of the water and the restoring waterplane for both ship and dock is provided only by the dock walls. In this condition, the dock designers normally demand a minimum $\overline{GM}$ of 1.6 m. When the pontoon is lifted clear, the waterplane is, of course, much larger. Free surface effects in a floating dock are also large.

Large angle stability is important not only for ocean transit conditions but for the careening which is necessary during maintenance and repair operations.

SHIPLIFTS

Shiplifts can be used for launching or docking or building but the usual application is for docking. In a typical arrangement a vessel is floated above a cradle on a platform which can be raised to bring the cradle and ship to normal ground level. There is a system of rails which can then traverse the vessel sideways until it is in line with a shed into which it can be moved. In this way one lift can serve a number of docking sheds. Clearly care must be taken to avoid straining the ship or the platform during the lifting operation. There are a number of hydraulic hoisting points along the length of the platform and these can be fitted with load measuring devices to assist the operator, the data being fed into a computer to calculate load distribution and so assess trim, heel and draught before lowering into the water.

Platform elevator systems which lift vessels from the water and transfer them to the shore can take vessels of up to 25,000 tonnef. In other devices the vessel is floated over a cradle and both are winched up an inclined slipway. Often a transfer system is provided so that a single lift system can serve a number of refitting bays. Shiplifts are claimed to be significantly more economical than the corresponding floating dock system.

Problems

1. A vessel whose launching weight is 25 MN with CG 5 m abaft amidships has the fore poppet positioned 50 m forward of amidships. Find the force on the fore poppet and the travel when the stern lifts from the following data:

Travel down slip, m	50	60	70	80	90
Buoyancy, MN	10.1	12.3	15.3	19.4	24.6
CB abaft amidships, m	47	40	33	26	19

Sliding ways 70 cm wide each side are proposed, with a length of 95 m. What is the mean pressure on the lubricant before motion takes place?

2. In a certain ship, the length of sliding ways was 163 m and the breadth 1.63 m. The launching weight was 9755 tonnef and c.g. estimated at 75.50 m forward of the after end of the sliding ways. Calculate the mean load per square metre on the ways. Assuming the pressure to vary in a linear manner from forward to the after end of ways, what is the pressure at each end?
3. A ship of length 152 m between perpendiculars is built on a slip with its keel at a slope of 2.98 degrees. It is launched on groundways which extend to the fore poppet only and have a camber of 0.61 m over their length of 183 m and a slope of 3.58 degrees. If the underside of keel produced at the fore perpendicular is initially 5.5 m above water level and the fore poppet is 18.3 m aft of the fore perpendicular, what are the draughts at the fore perpendicular and at the after perpendicular when the ship has travelled 61 m down the slip?
4. A ship is launched from ways 219 m long, with a camber of 457 mm and a declivity of 2.69 degrees. The slope of the keel is 2.46 degrees. If the minimum height of stopping up is 762 mm, find the height of the fore poppet above the after end of the ways when the ship has travelled 61 m down the ways. Assume the fore poppet initially at the fore end of ways.
5. Construct a set of launching curves from the following information:

launching weight	5230 tonnef
CG abaft midships	7 m
fore poppet before midships	69 m
after end of groundways from c.g. at rest	100 m

Travel down slip (m)	30	60	75	90	105	120	135
Buoyancy (tonnef)							
before stern lift	830	1960	2600	3350	4280	5600	
after stern lift					4050	4700	5550
Moment of buoyancy about fp before stern lift (1000 tonnef m)	132	219	282	356	450	585	
Moment of buoyancy about AEGW (1000 tonnef m)				42	76	160	316

(*a*) When does the stern lift?
(*b*) What is the maximum force at the fore poppet?
(*c*) What is the minimum moment against tipping?
(*d*) How does the ship leave the ways?

6. A ship weighs 28,500 tonnef at launch. The fore poppet is 72 m before the CG of the ship. The after end of the groundways is 155 m from the CG before the ship moves. The following table gives the data derived for the passage of the ship in full contact with the ways:

Travel, m	120	135	150	157.5	165
Buoyancy, tonnef	9000	15,600	24,400	29,200	35,000
CB abaft AEGW, m	—	7.5	21.5	28.0	33.0

Deduce a set of launching curves and pick off the important data.

7. A floating dock of rectangular bottom shape, 122 m long and 27.4 m wide floats, when empty, at a draught of 1.07 m. It is used to dock a ship of 3658 tonnef displacement, 110 m long, which is symmetrically placed in the dock. The weight distribution of the ship is symmetrical about amidships and has the values shown in the table below:

Distance from midships, m	0	6	12	18	24	30	36	42	48	54
Section from midships		1	2	3	4	5	6	7	8	9
Weight per section, tonnef		294	289	276	256	228	194	152	103	38

Draw the curves of load, shearing force and bending moment for the dock and ship combination, in still water of 0.975 m^3/tonnef.

The weight of the dock may be assumed equally distributed along its length.

8. A vessel has a launching weight of 5893 tonnef, the CG being 7.9 m abaft the mid-length and the fore poppet 70 m before the mid-length. Construct a launching diagram from the following data:

Mid-length abaft AEGW, m	0	6	12	18	24
Buoyancy, tonnef	2601	3241	3901	4602	5415
CB abaft AEGW, m	39.9	43.6	48.2	52.7	56.4

State:

(*a*) distance of mid-length abaft the after end of groundways when the stern lifts;
(*b*) force on fore poppets when the stern lifts;
(*c*) reserve moment against tipping.