Hydrostatics and Stability

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Lecture No. # 35
Safety Regulations
(Contd.)

Good morning. So, we have come to the, 34th, 35th lecture of this series. We will continue with the safety regulations.

We were talking about the different stability regulations followed by the different navies, which have, as I said, been adapted from the main stability regulations developed by the international maritime organization of the UNO. We discussed in the last class about the different adaptations to the code performed by the US Navy. They have developed the code for their own particular uses and they have made a series of codes, a series of laws by which they, they make sure, that the hydrostatic and stability requirements of the ships, of the U S ships are met in the sea.

Now, we are more or less completed on the US, some of the rules. Now, in this course we are not going very much into the details of the various rules. But we are just going over them in a, in only the main points of them, we will just go through the main points and we, overall we give an account of what are the different laws, that we are, that are followed.

Now, the next series, the next important navy, which has adopted many of these rules for the, for their purposes is the UK navy. So, we will see how some of the rules have been developed by the U K navy.

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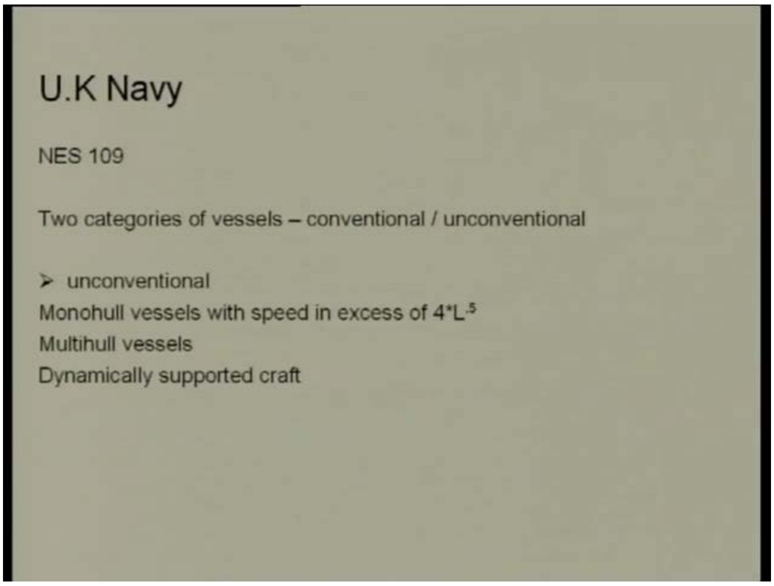

Now, the UK Navy has framed its rules according to a code, which they call, that booklet is, that series of code is named as NES 109, the full form, it is not that important. So, NES 109 is the, like the series of something, like the (( )) codes.

We say that NES 109 represents the series of codes that are followed by the UK Navy. UK Navy does their stability analysis, they categorize the ships into a few classes, the main, the primary vein, which they classify the ships or the vessels are in terms of conventional and unconventional crafts. So, they call some crafts as conventional and others are unconventional.

The conventional crafts are the ordinary ships, that we are familiar by now. We are talking about the different types of tankers, oil tankers, bulk carriers; the other types of vessels like ore carriers or container ships or even passenger or cruise vessels. So, these kinds of vessels, the ordinary kind of vessels are also small boats, inland water vessels, (( )). All of them come under the category of displacement, come under the category of conventional crafts, the kind of crafts for which we have been, we have developed the course so far.

We have hardly talked about unconventional crafts because that is in advanced stage of naval architecture design; so, this is it. Since, this is a preliminary course on hydrostatic and stability, the concepts of stability we deal with, the principles of stability associated with the conventional crafts, that is, the crafts like we have studied.

Now, there is another set of vessels, which come under different category of unconventional crafts. These are vessels that are different from, different from the ordinary types of crafts. One of the differences, one of the main types of craft is a dynamically supported craft. If you remember, I have already talked about this in about 3 classes back, we talked about the, what we call as, what we call as the dynamically supported craft or DSC.

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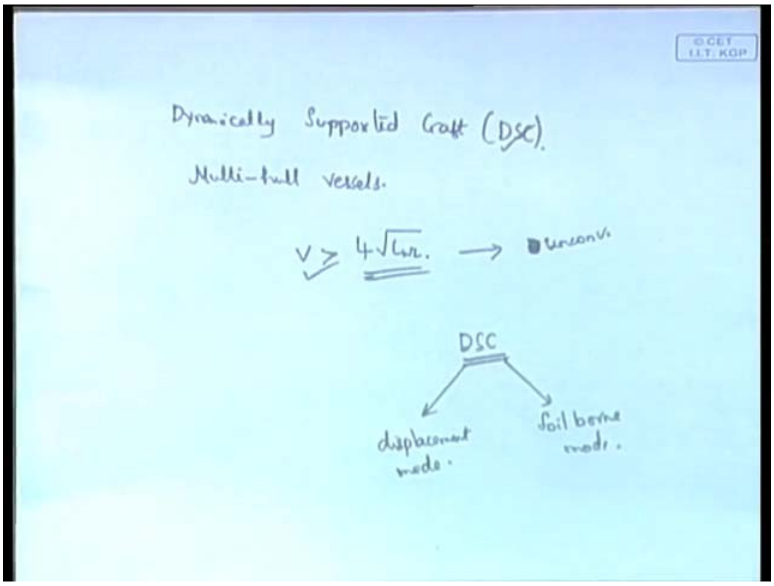

These are a particular type of crafts, which have some of their properties, their hydrostatic properties and their, even their hydrodynamic properties different from that of the conventional crafts. So, this is one category, the dynamically supported crafts.

Now, another category of ships, you, another category of crafts are possible, these are called multihull vessels. So, this is another type of vessel that is called a multihull vessel. A catamaran for instance is an example, a trimaran is an example, there are pentamarans, all those kinds of things. These are vessels, which have multiple hulls. Now, we will take some look at some of the unconventional crafts. So, unconventional crafts in general, we have the multihull vessels and the dynamically supported crafts.

Now, what do you mean by dynamically supported crafts to a, last time I told you that I will, I can, I can give you some pictures of this as I...

Now, even vessels, which have a speed in excess of 4 times L power, 4 times root L; 4 times root L, w L in fact. This thing, when the velocity is greater than this, means the speed of the ship exceeds 4 times root of LWL, where LWL is the length between lengths of the water line. Now, if velocity exceeds this, then that also we categorize it as an unconventional craft. So, these are high, high speed, very high speed vessels.

So, all these kinds of different vessels come under unconventional crafts and the UK navy has a series of regulations dealing with them. Similarly, a series of regulations dealing with the conventional crafts.

Now, like I promised in the, in few lectures back, I have some slides of what we call as hydrofoil boats, that is, I already said, that we have DSC, the dynamically supported crafts; we have different types of dynamically supported crafts.

One of the main types of dynamic, as I said in that last class, the 2 types in which the 2 types are: displacement. Now, a dynamically supported crafts can travel in 2 modes of, it has 2 modes of travel. One of which is called as the displacement mode and the other is called as the foil borne mode.

Displacement mode is the mode of the vessel whereby the ship travels such that the weight of the ship is balanced by the buoyancy. The ordinary condition of a conventional craft, but, but remember, it is not a conventional craft, but it is travelling in the type, in the mode of a conventional craft. So, in that case, the displacement is equal to buoyancy and the Archimedes principle holds and the ship moves with the constant, ship moves just like an ordinary ship or like a tanker for instance. So, that that is what we call as the displacement mode of that dynamically supported craft.

Now, another possibility in which the dynamically supported craft can travel is what we call as the foil borne mode. Now, an instance for this is when the ship is not supported by the buoyancy, but the ship is supported by the lift forces from hydrofoils. So, just to mention, that you have to, I did mention there are things called foils, we, that is, we call them as aerofoils or hydrofoils.

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This picture for instance, is an example of a hydrofoil craft in which you see these things. Here, you will have foils, this, this, this region you are seeing here, here. There will be a region in, below the water, a kind of pontoon below the water that is actually a hydrofoil. So, these, this is the general picture of a hydrofoil craft.

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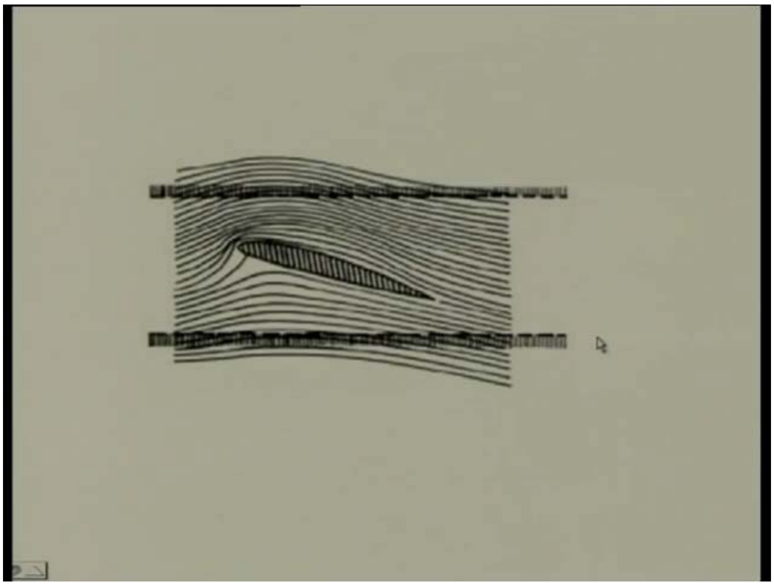

So, now, how does a hydrofoil work? Now, we, how does the foil in turn works?

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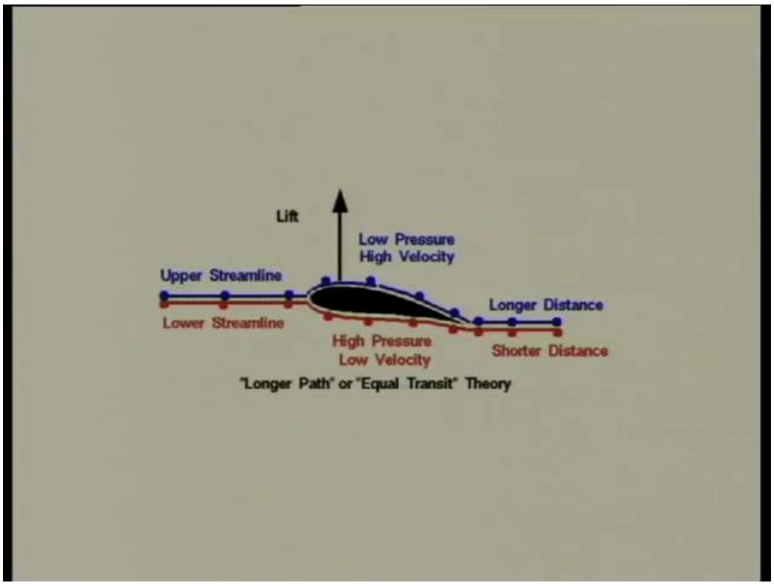

Though not that important for this course, we will just mention quickly, that is, this picture represents how the, this, an example of a hydrofoil or an aerofoil.

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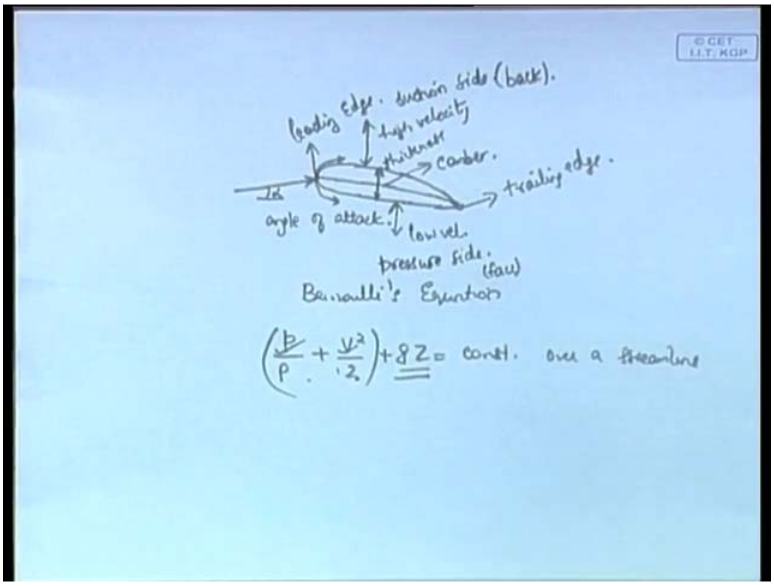

So, we, this is the shape, this is the shape of hydrofoil, now this is known as a camber. This we call it as a camber, the midpoint, the midline, the camber of the hydrofoil, this we call as the thickness of the hydrofoil. So, the camber of the hydrofoil and this is thickness of the hydrofoil. Then, the angle at which, this is a hydrofoil, let us consider hydrofoil and the, the angle at which the water enters here is known as, this angle is known as the angle of attack alpha or it is actually the angle between the, ok it is not drawn, it is the angle between the hydrofoil and the angle at which the water is hitting the hydrofoils. So, this is called as angle of attack.

These are parameters upon which the, these are parameters upon which the, the lift produced by the…

Now the concept of the hydrofoil is this. When water flows like this, when water flows, water comes, here it will split into 2, some water will go above, some water will go below. Now, you will see from hydrodynamics or you will see, you will, when you doing the calculations from hydrodynamics, the hydrofoil is designed in a way, that this part of the hydrofoil, means this, this, this surface of the, below this, the under, under the down part of the hydrofoil, this region of the hydrofoil is really, will be associated with low velocity. And this region of the hydrofoil, the above part of the hydrofoil will be associated with high velocity, high velocity of the fluid. Now, therefore, when the fluid, so when there is a hydrofoil, the fluid comes from one side and it hits the hydrofoil at the, this edge, we call it as a leading edge, this edge, the leading edge of the hydrofoil, and this edge we call as the trailing edge of the hydrofoil.

So, you have a hydrofoil here and the water comes and hits the leading edge and the water splits into 2, some water goes above the hydrofoil, some water goes below the hydrofoil. The region, that goes below the hydrofoil has a lower velocity, the one above has higher velocity. And therefore, this is the distribution over which the, this is velocity distribution over the entire domain.

Now, what will happen is that in case you are not familiar already, there is a formula called Bernoulli's equation. This Bernoulli's equation states, that the pressure and velocity in a domain, the pressure of the fluid and velocity of fluid of course, in case of invisit fluids, invisit fluids means flows without viscosity and to a large extent the flows outside, the flow outside, the flow far away from the surface of the body can be considered as invisit and therefore, Bernoulli's equation states, that p by rho plus v square by 2, this is generally known as the Bernoulli's equation over a streamline.

So, the Bernoulli's equation states, that p by rho, where p is the pressure at the particular point, rho is the density of the fluid at that point, plus v square by 2, where v is the velocity of the fluid at that point plus GZ, where Z is the, GZ is the potential, the, the geopotential of that point, Z is the height of that point above some datum. So, that is equal to constant over a streamline.

Now, therefore, you see, that from this equation directly we can see, that when p increases or when v increases, the velocity of that fluid on a particular region increases, the pressure at that point tends to decrease. Similarly, when the v decreases, the pressure at that point tends to increase because p plus v square, as you can see here, p plus v square, this whole thing, if you consider this as a constant, this plus this is a constant. So, if this increases, this decreases, this, this increases this decreases, so that the sum is the constant. So, this is the Bernoulli’s equation.

And as a result of Bernoulli’s equation I have said, that this is the region of low velocity and this has become a region of high velocity. And the velocity distribution remember has come because of the shape of the hydrofoil. The hydrofoil is designed in such a fashion that the lower region gets low lower velocity and the high above region gets higher velocity.

So, this, so, and this lower region is what we call as the pressure side of the hydrofoil. This is the pressure side and this region is known as the suction side of the hydrofoil. This is also known as the face and this is known as the back; different, synonyms for the same thing, this is the. So, when you have a hydrofoil, you have a hydrofoil, you have the region above the hydrofoil. So, the region above the hydrofoil is having, is known as the pressure side, is known as the suction side and the region below is known as the pressure side, and this is the back, this is the face.

So, what happens? We have already seen that you have higher velocity on the suction side, lower velocity on the pressure side. So, as a result of which, as a result of the Bernoulli’s theorem, automatically this region becomes high pressure, this region becomes low pressure.

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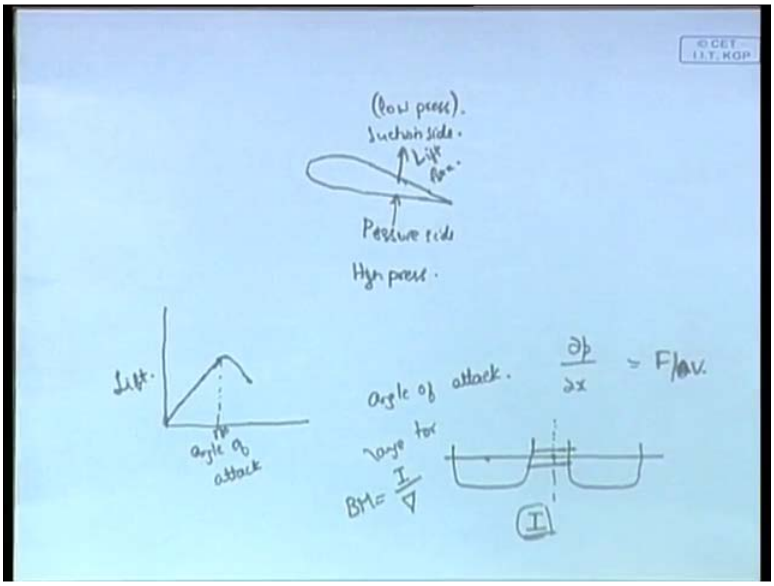

Therefore, you will see that, so if you have the hydrofoil, so this is the pressure side and this is the suction side. So, at the pressure side you have high pressure and at the suction side you have low pressure. So, as a result of which what happens, that is always a force from a region of high pressure to a low pressure. As you know, pressure gradient is the force.

So, dou p by dou x for instance, is actually force per unit area, force per unit volume sorry. So, dou p by dou x represents the force per unit volume. So, there is force acting between this region and this region. So, from here a force acts to this side like this, a force acts, this force is known as the lift force. So, the lift force is purely due to the pressure effect. So, the pressure, high pressure on one side, low pressure on one side of the blade causes a lift through the, it causes a lift, which pushes the blade up. Therefore, there is a tendency for the blade to go up. This is the concept on which the aeroplane also works.

That is, when you have the aeroplane, you have the wings; you will have an aerofoil in that case, not a hydrofoil. The only difference between the aerofoil and hydrofoil is the fluid medium in which it operates. So, in an, it is, both are foils and one operates in the hydro mode, the other operates in the aero mode. So, one becomes hydrofoil and other becomes an aerofoil.

So, the hydrofoils, I mean, in the case of aeroplane you have an aerofoil. So, the air comes from one side, it flows in the same fashion I have described, it comes at some angle of attack and because of the pressure difference created on both sides of the wing, it lifts the wing. Remember, it lifts the wing on both sides.

Now, if the lift force is enough to balance the weight of the airplane, you will see that the airplane, it is enough to hold the airplane in the air. So, at some height, if the lift equals the weight of the aeroplane, it remains at that height and in cases. If and at the time of take off you want the lift to be greater than the weight of the aeroplane, so that it accelerates upwards, that is, the net force upwards, so it accelerates upwards. That is what happens during the... So, the lift will be and this lift can be modulated, this lift will depend upon the pressure distribution, that can be modulated by changing the angle of attack.

You will see that any, any aerofoil will have, an angle, lift, that keeps increasing with the angle of attack. If this is the angle of attack, the lift on the, lift on the hydrofoil or aerofoil will keep increasing. It will reach a maximum at about 17 degrees and then, after that it will start decreasing. That is not important here, but anyway, it reaches a 17 at around 17 or 15 degrees.

You will have the region of maximum lift or the maximum lift coefficient that is something related to this lift only. It is a coefficient, which parameterizes lift; the value of it is a non-dimensional value of lift. So, this is the concept of lift. So, this is a process by which a hydrofoil can generate a lift.

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So, as we have seen in this picture these things, which are the hydrofoils here, there are hydrofoils below here, like pontoons there are some foils, it is not pontoons, it is foils. So, you have in that direction horizontal foils. These foils will generate their own lift, they will generate. Due to this flow there will be a high, they, they will generate their own lift and this lift will balance the weight; this lift will balance the weight of the, weight of the ship. So, this ship, its weight is balanced by the lift produced by the hydrofoil.

Now, so that difference in, difference in pressure between the upper and the lower sides of the hydrofoil will give an upward force, which is the lift, which will be now and in that will give you per unit length and when you integrated over the whole length of the ship, you will get it over the whole length of the ship, the total lift force and this total lift force will become equal to the weight of the ship.

Therefore, as you see here, the weight of the ship is now not balanced by the buoyancy force, which is the according to the Archimedes principle, but the weight of the ship is now balanced, according is now balanced by the lift force due to hydrofoil. So, we call it as a foil borne mode or a foil mode. So, this hydrofoil operates in the foil borne mode in the foil mode.

And, and there are advantages as you can see, very much smaller portion of the ship is under the water, as you can see here, the wetted surface area. We have already defined the wetted surface area, the surface area of the ship, which is exposed to the, exposed to the water, that is called as wetted surface area. Now, wetted surface area is obviously less here, much lesser here. You will see, that the direct consequence of the lower wetted surface area is that because if it, if it were, the whole thing were displaced, all this area under will be wetted surface area. So, only in this, only this much is a wetted surface area.

So, because of that the net resistance or the drag on the ship will become very much less in case of a hydrofoil. So, that, but it has its own problem and, and also of course, when the, when the resistance is less, the ship can travel with much higher velocities and therefore, hydrofoil crafts travel much faster than conventional crafts. So, these are some of the unconventional crafts.

So, and of course, the other one is multihull vessels, which I mean I have not got any picture, that multihull vessels are simple. You will have for example, if you have a catamaran, you will have a twin hull, there are 2 hulls that are under the water; they are connected and that is the difference.

Now, if an intuitive person, student can easily develop the theories for a multihull vessel. For instance, the development of the whole theory, that he has, we have developed for a single hull vessel will now… One of the problems with multihull vessel, as you can already guess, is one of which is, one of it is, what is the thing, that changes very much due to the, due to the multihull vessel? Volume of course, because there are 2 hulls, the volume under will increase, so that, that is the one; wetted surface area will increase, all those things will increase.

The main difference is going to be in I, which is the moment of inertia about the centerline, the moment of inertia about the centerline because note, in this case you will be having 2 hulls like this, like this and they are connected of course, and that is all that, the connected and all that, bend. Now, it, here also they will be connected, that is a, is designed. Now, these will be 2 hulls that are connected like this. So, this represents for instance a catamaran.

And so, what we have to see here is this I. Now, what is the centerline? This is no longer the centerline, this does not become the center, this becomes the center, this is the center of the, like this, this becomes the centerline of the whole vessel, the multihull vessel.

Therefore, we take I, you will be taking I, about this center will be I B l B cube of this plus A into this distance square l B cube of this plus A into distance square of this using the parallel axis theorem. So, this gives to the net I for the ship.

Therefore, you can see, that the BM, which is given as, which is the metacentric radius I by del will be very large, very large for, that means, it will be very large means, in general you will see, that B will be very low. The net center of buoyancy will be very low and the metacenter will be slightly higher, therefore BM will be quite larger than an ordinary ship.

And G of course as such does not change, GM increases because M is now slightly higher, G is as the same as for ordinary ship. So, GM increases and therefore, the stability of the ship will increase definitely. But of course, as you can see, volume has increased; wetted surface area has increased, as the result of which the resistance drag will increase. The power requirement will increase, as the result of which more power is required to…

You need higher diesel engines if a monohull vessel requires, let us say, 20000 kilowatts. A multihull vessel will be requiring 35000, 40000 kilowatts. So, that much difference in the diesel engine power requirement is there. So, that much, that much more consumption is there. So, that is the problem, but stability is more. So, these are some of the advantages and disadvantages of a multihull vessel and so these are the unconventional crafts that the UK Navy is talking about.

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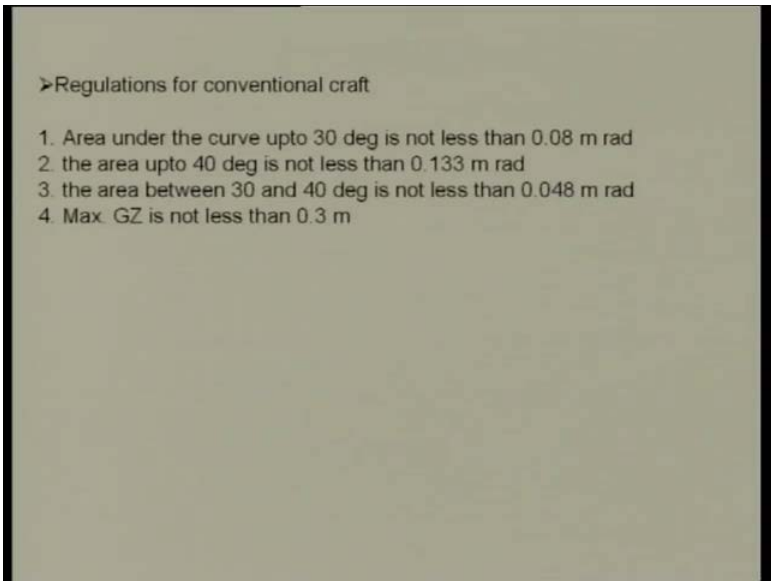

Now, let us look at some of their rules. They have a, the conventional crafts, they have series of rules, some of them is, that one of them is, that this thing, that is the area.

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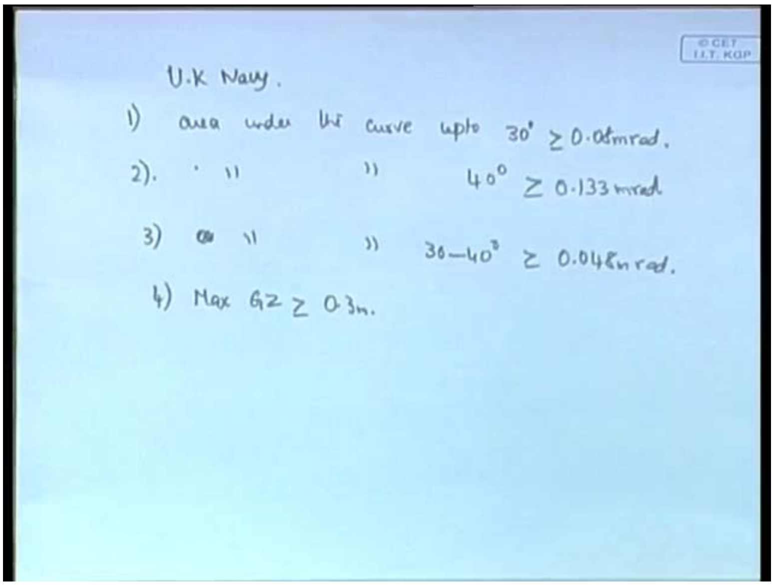

So, everything about that stability of ships, conventional crafts definitely, probably not unconventional craft so much, that is, it is all about the area under the GZ curve. So, always you are going to talk about the (( )) moment.

So, the area under the GZ curves, so area under the curve up to 30 degrees should be greater than or equal to point naught 8 meter radians. Note that these are all rules for the

UK Navy; there will be slight differences between the rules of the IMO, rules of the US Navy and the rules, if you, UK Navy or German Navy, there are slight differences.

Now, 2, up to same thing area under the curve, up to 40 degrees should be greater than or equal to 0.133 meter radians. So, the dynamical stability, dynamical stabilities of course, delta into GZ, but if you consider just the GZ curve, delta is just a constant; it is a weight of the ship. Now, the area under the GZ curve up to 40 degrees should be greater than or equal to 0.133 meter radians. Now, area, same thing, area of the curve between 30 and 40, so area under the curve between 30 and 40 should be greater than or equal to point naught 48 meter radians.

And 3 rules and then 4th one is that the maximum G Z, maximum G Z should be greater than or equal to 0.3 meter. Now, always your righting moment, the maximum righting moment should be in the range of 0.3 meter. So, these are some of the... So, you can see, whatever be your type of ship, these are conventional crafts, we are talking about vessel. Of course, it we are talking about mainly vessels of larger dimensions, we are talking about 100 meter vessels or, or anything starting from these are all conventional craft, starting from about, I believe, about 30 meters up and going up to about 200, 250 meters.

So, these vessels they should have their maximum GZ definitely greater than 0.3 meter and all these formula, all these regulations regarding the amount of area and between 0 to 30 and 40 degrees.

These are some of the rules. Then, they also have, the UK Navy also has the series of rules regarding passenger safety for passenger vessels.

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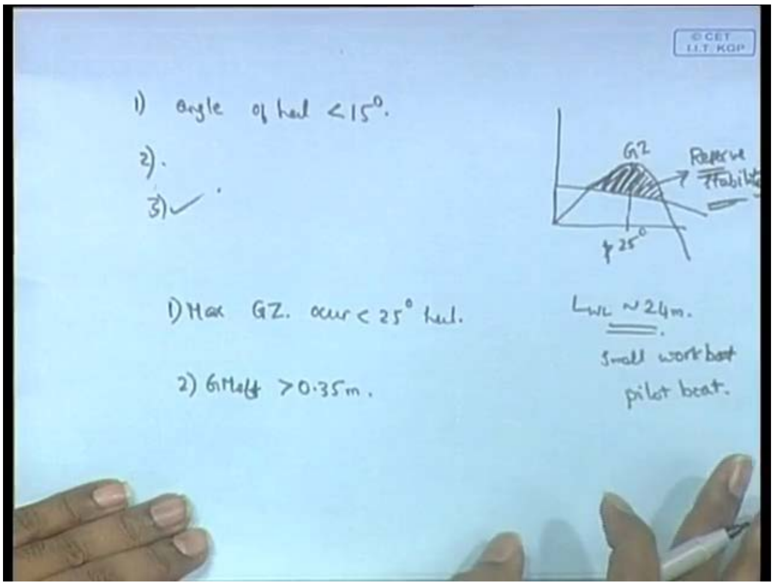

Now, in case of passenger vessels, we are talking about that vessels, that carry passengers only, mostly it says, that always at any, if the vessel is carrying passengers, note that we talk about passengers, when we talk about passengers we are not talking about crew as such. That is the, anyways, any ship will, vessel will have crew, we are talking about whether it be a container ship or an oil tanker, it will definitely have. So, passenger ship is the different types of vessel, which is the kind of crew ship, which carries passengers and when you have such a passenger vessel, it has some other requirements in addition to the requirement that are given for the ordinary conventional ship.

These are also conventional ships, we are, passenger vessels are also conventional ships. These vessels have additional rules, that is, the angle of heel should always be less than 15 degree, so you cannot heel more than 15 degree. Whatever be the conditions means, whatever be the wind turning passenger. Now, another thing that happens due to the passenger vessels is that special case when you have all the passengers crowding to one side. If it is the crew's vessel, suppose they are sightseeing, all the passengers crowding to one side, the heel, in that case also, that heel is also considered. So, 3 cases, wind turning, cargo 4 cases and finally, the passengers all crowding to one side. So, all these conditions will whatever be these things happening, it should, the angle of heel should be less than 15 degrees.

Then, it says, that the angle of heel are the righting arm at, we have already talked about what we called as the 1st statical stability and the 2nd statical stability angle in the GZ curve. We are already seen in the 1st angle of statical stability and the 2nd angle of statical stability.

Now, in, in that curve, the GZ at the point of 1st statical stability should be less than half the GZ of the maximum. So, maximum GZ, if x is the maximum GZ, this at phi ST1, what we call as the phi, the call as the statical angle at the statical stability, 1st statical stability angle, the GZ at that angle should be at least half of x, it should be at least by x by 2.

Then your reserve of stability, we have already defined what is the reserve of stability. If you draw the GZ curve and if you draw the heeling arm curve, let us say in case of the wind heeling arm, if you draw the GZ curve and the heeling arm curve, the total area is, the total area, total area under the GZ curve is one thing and the area between the, area that is outside the, outside the heeling arm curve like this, so this total area and if you draw the heeling arm curve, this angle, this area. So, this area is there, the whole area is we call what we call as the reserve stability, area of reserves, so the reserve stability. So, this should at least be half of the total that is another rule associated with passenger vessels. So, 3 rules, 3 rules.

Now, you will see, that if you compare the 2, between the UK regulations and the US regulations, you will see the conclusion, that the UK regulation are much more stringent than the US Navy regulation, means, the UK, UK navy has more stringent regulations than the US navy. It is stricter in that sense means, the criterion are more tighter. So, you, they are less, means you cannot, we has relaxed as in the US case, that you can see if, if you compare the 2.

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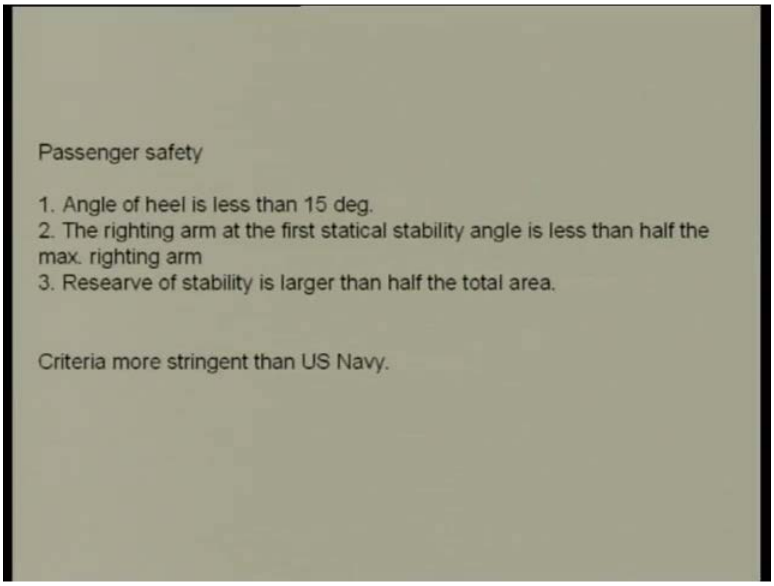

And then, now what we have, now we have the condition of small boats now. We have another, another type of series of vessels by the UK Navy, that is, the UK Navy, the 3rd series of a, 1st we had the conventional basic regulation, then some about passenger regulation.

Now, when we consider the small boats, they are talking about boats less than 20 to boats of the length of the 0 to, not 0, at the range of 20 meters or 25 meters small vessels. Now, these vessels have their own series of rules. They have, they, it says, that the maximum, maximum GZ, it says the maximum GZ for such small boats, which are talking about less than 25 meter long or 24 meter load is the, there is LWL is approximately of the range of 24 meter, this is what we are calling as small boats. Call it as small, they call it as small work boat or pilot boat, they are all easily piloted. So, we have them, we, says that, the rule says, that the maximum GZ should occur less than 25 degree heel.

Now, when you draw, that means, this should not be greater than 25, it should not be greater than 25 degrees. The maximum, the maximum GZ should not occur at an angle of heel greater than 25 degrees. That is the 1st rule.

Now, GZ, when GM is effective should now, the GM effective, which is known as the effective metacentric height, you know, that it is the metacentric height, that is 1st of all. We have the basic metacentric height accounted for by hanging loads free surface effect, transfer of loads. When you account for all that, you enter with what we call as GM effective.

And in case of such GM effective, which is the effective metacentric height, we say is, the rules say, that for small boats, the effective metacentric height should definitely be greater than 0.35 meters. So, this is an important rule.

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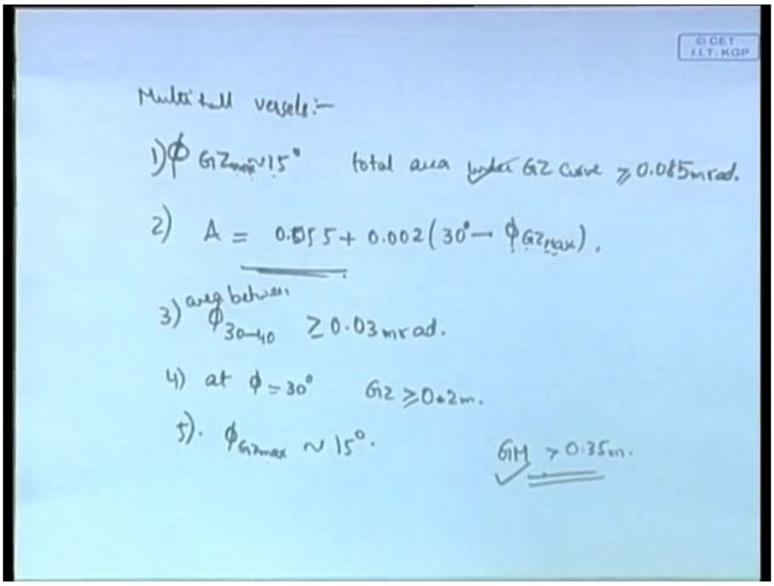

Then, that are some, some kind of rules for multihull vessels as well. So, they, their rules for multihull vessels says, that 1, it says, that if GZ, that is the maximum righting arm, is occurring close to the region of 15 degrees, then the total area under the curve, total area under the GZ curve should be greater than or equal to point naught 85 meter radians.

Now, you will see, that in case of small work boats we are talking about, the pilot boats are the work boats at, of the range of 24 meters, these boats will have their maximum GZ, the maximum in the curve will occur very early, close to around 15 degrees.

We have already seen that in case we have larger ships, we have already drawn the GZ curves of larger ships. There, I mean, in case you have the larger ships like a, like a large passenger vessel or a container ship, if you draw the GZ curve, you will see, that the GZ occurs mainly in larger angles, be it occurs around 40 degrees or 45 degrees. It, the larger the ship in general, the GZ, the position of maximum GZ moves further down; the heel, it goes further down. In case of small work boats, you end up with the angle of heel, maximum GZ occurring at an angle of heel around 15 degrees. If that is the case, it says, that the total area under the curve should be greater than or equal to point naught 85 meter radian; that is the 1st rule.

And the 2nd rule is that or this rule can be stated in general, that the area in general should be point naught 55 plus 0.002 into 30 degrees minus phi, where GZ maximum is occurring. So, the, what this rule, what this equation states is, this is the area, this, this much of area should at least be here. So, if phi max is occurring at 15 degrees as this 1st rules says, if GZ max is, this is GZ max, so if GZ max, phi of the GZ max, that is what it is, so if phi of the GZ max is 15 degrees, you put it here, you will get an area of point naught 85 meter radians. So, this is the basic, this is the general rule for the amount of area under the curve you should have.

If you have a small pilot boat and if you know the phi of GZ maximum, that is the angle of heel at which GZ maximum occurs, then you are relating the area to this then.

Now, now, another rule says, that the area phi between 30 to 40 should not be, should be greater than or equal to point naught 3 meter radians, this is another rule. Not phi, the area under the curve area between, so the rule says, that the area of the GZ curve, so when you draw the GZ curve, we have already seen 1st condition holds, that the, it should be, means, we see, we see, that roughly the phi comes around 15 degrees and provided you know what is the phi GZ maximum, which is the angle at which the heel, at which the GZ is maximum, you have an expression for the area, area under the curve, minimum area under the curve, that much area is required for stability.

Now, also in the angle, between 30 and 40 degrees, so in the region between 30 and 40 degrees, you should have point naught 3. It should, it does not have to be 40 degrees, it can also be the angle of flooding. So, the minimum angle of flooding, so in the angle between 30 to, 30 to either 40 or the angle of flooding, whichever is smaller, the area between, area under the curve should be at least point naught 3 meter radians, that is one rule.

Then, at 30 degrees, at phi equal to 30 degrees, the GZ should at least be equal to 0.2 meters. So, at an angle of phi equal to 30 degrees, GZ should at least be equal to 0.2 meters. So, this is very important rule.

Then, now, it also says, that the phi of GZ maximum should roughly occur around the region of 15 degrees. It actually notes that this phi, this GZ curve is actually the property of the ship. So, it has nothing really to do with the wind, that is occurring or the turning, amount of turning, that is happening or, or the passengers on the board, or the missionary on the board or propulsive system, nothing.

GZ curve is the property of the hull structure; it depends on the structure. That means, how it depends upon things like the block coefficient or the prismatic coefficient, different, depends upon the length, breadth. It depends on the lines plane, it depends on the hull shape, means it basically depends on the hull shape. So, that is the, that is what GZ curve depends on.

Now, this G Z curve, therefore it really defines, whether your ship is stable or not. One quick way to look at it is, look at for a small boat. The rule says, that your phi GZ, it should be, phi of GZ maximum means, the angle at which you are having the maximum GZ, should be somewhere around 15 degrees.

If you are, if you are talking about a ship, that has a length of about 20 meters, as we have said 24 meters, these, this, what we call as the small work boat or a small boat, a ship of this, a boat of this length and if you end up with a GZ maximum occurring at an angle of heel, let us say 30 degrees, then the conclusion you can right away draw is, that the ship is unstable. Something is, it is, it is not going to work, it is going to, somewhere at some point it will capsize, means it is an unstable ship because some, some, it can be due to a wind heeling arm, it can be due to, maybe it is inherently unstable, means it just does not float, it is just not the proper design, that is, phi of GZ maximum for such a, remember for a small boat.

But if you are talking about a large ship, your phi GZ maximum should be somewhere around 35, 40. So, these are some basic guidelines you can apply when you are, when you can just look at a ship GZ curve. And some, in most of the case, 95 percentage of the case you can directly say, you, whether the ship is, at least from the 1st inspection, whether the ship is ok or not.

So, this is one thing, the pilot boat if you are talking about, small 25 to 30 meter boats, you should have phi somewhere on the region of 15 degrees; for large ships, phi around, phi where GZ maximum is occurring, occurs around 35 to 40 degrees. So, this is the some basic guidelines. So, these are some of the rules of the UK Navy.

And note, that you try to always, to have your, this another rule, which we mentioned for the large ship also, for the conventional craft, the, for passengers also we mentioned this, the, the metacentric height GM effective should always be greater than 0.35 meters, that is the fundamental criterion. It is true even for the small boats. Even for the small boats, the GM effective should always be greater than 0.35 meters. GM is the, of course in small boats, there is no such thing as free surface effect because you are not going to have tanks in a small ship, small boat.

So, in, you can say, that the metacentric height not ineffective, just the metacentric height GM of this kind of small boats, GM should always be greater 0.35 meters. These are some important criterion there have to be followed while studying the stability criterion. These are followed by the UK navy.

Now, similarly, similar, similar series of regulations are available for small internal water vessels. Internal water vessels means, internal water in general means vessels, that ply on, ply on water, other than in the open ocean it travels inland waters, inland, internal water are, it is inland waters are those, that travel like in lakes, small estuaries, small lagoons inside or such small rivers. It travels in such those kind of boats are called as internal water vessels.

Now, there are a series of laws that UK navy has regarding that also.

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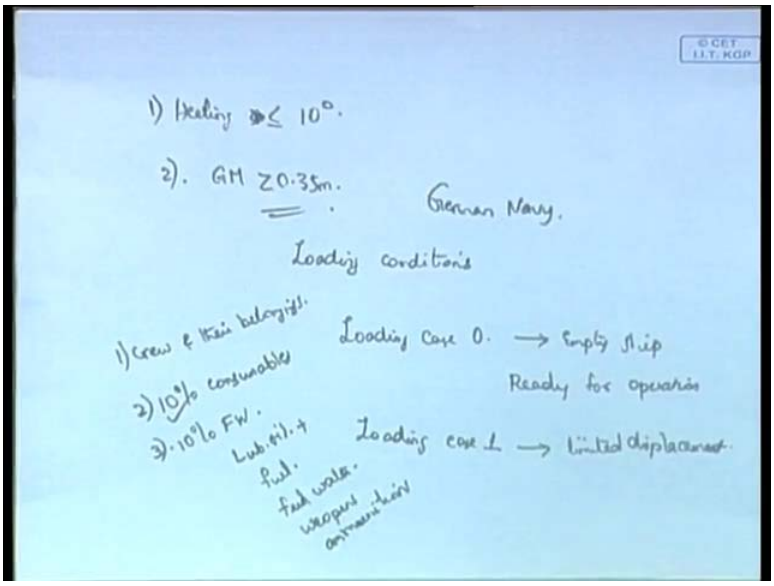

Now, one of the main rules is, that heeling in such small vessels, heeling always does not exceed. That means, it should be always less than or equal to 10 degrees. So, the heeling of such internal water vessels, that is, the vessels in such lakes should always be heeling, should be less than 10 degrees and, and of course, you should have the GM. GM should always be greater than or equal to 0.35 meters, this also holds.

So, these are, some of these are such basic regulations, there are a lot of more regulations, means, just by satisfying this, ship will not be classified, you have to follow a lot of other guidelines. When if your ship has to be classified, let us say by the Indian register of shipping or by American bureau of shipping, they have to follow a completely different, they have to follow a lot of other guidelines as well, if they have to be certified. So, these are some basic things.

So, we talked about different kinds of, so we saw, that the basic safety regulations have been developed by the international maritime organization and they have been adapted by many people, like the US Navy, the UK Navy. UK Navy, in general, having more stringent conditions than the US Navy and they have their own regulations for different types of vessels, and that is an important thing, that is, these regulations developed is not, it is not for, it is not a uniform thing for all type of vessels.

So, different types of vessels, which are used for different types of conditions, mean, it has different fields of operation or the different modes of operations, their methods of operations are different, their purpose of operation are different. So, when everything is different like this, they, they, they have different series of rules pertaining to them. So, far as we have seen, we split up the rules for UK Navy, they split the rules for conventional, unconventional crafts, series of rules. Then, they have a series of rules for the passenger vessels, then more rules for small pilot and small type boats and pilot vessels, then, then similar rules for the internal water vessel.

So, like that, you have then another country, which follows stringent rules, is Swiss regulations, they are also important, but it is not we are not going into it because there is not that much time and it is not that important. So, there are, these are some of the regulations. Then, another series of regulations followed mostly are by the German Navy. They have a very stringent set of regulations as well.

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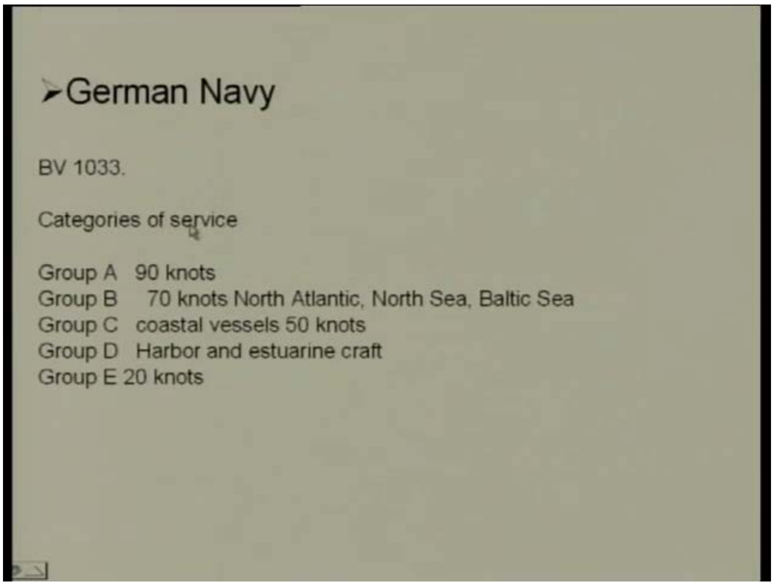

Now, these, German Navy have their own series of regulations and those regulations come under a booklet by the name of BV 1033 that is the name of the booklet, which contains the German regulations for different types of vessel.

Now, the German Navy, first of all categorizes a vessel into different sections, they divide the vessels into different categories. So, this is how, they first of all categorize the vessels, they are characterized on 1st category. First of all, instead of categorizing mainly on the type of craft, it is, means, whether it is for a conventional or an, like the UK Navy, it is, that is one way of categorizing the crafts. You, German Navy follow the slightly different procedures. They, they categorize the crafts on the types of seas on which the ship is going to ply.

So, if the ship is going to ply on winds, between winds in the, in the excess of 90 knots, we are talking about very high winds here, 90 knots is 45 meter per seconds, so these are very high winds. Note, that in general, if, even if you consider a hurricane, a hurricane travels at about 150 knots, probably 150 or 160 knots, so 90 knots is very high winds, very strong winds. And when you have these kinds of winds, there are some regions of the ocean, which are always subject to this kind of winds. Some of the very rough areas of the world subjected to these winds, for instance north Atlantic, some regions are like that or the Baltic sea, this, some of these regions are very, always they are very exposed to such winds. So, these winds, these vessels that ply under the strongest winds are called as group A vessels. Then, they go above 90 knots; they go in winds of 90 knots.

Then, group B vessels are vessels, that travel, that are exposed to wind in the range of 70 knots.

Group C in the region of 50 knots. Now, when you are talking about 50 knots, we have come to some very rough regions of coast. They have 50 knots, some of the regions of Florida coast or the, even the North Carolina coast, some of these regions have stronger winds up to, up to 50 knots, that is, 25 meter per second.

Then, when we come to lower winds, we are talking about, maybe the coast of Bay of Bengal for instance or the coast of Arabian Sea, we come to winds probably about 30 knots, 20 knots or even less, that distance meter per second. These are strong, of course, for a, for these region these are strong winds and 10 meter per second is not much, these winds. So, when these winds occur like these regions, they we called them as group E, group E, region of group E category of vessels.

So, so from A to E, they have split the categories into different vessels, which, which sail in different types of winds. So, these are the, are and just remember the name BV 1033, that is the, so this is the, that is the type of, that is the name of that code.

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Now, also one thing to note is different types of loading conditions. Now, different types of loading conditions are important, though are not, we are not going, that is, this is how German Navy, this is again further adopted by the German Navy only of course, also in some form or others, it is adopted by other Navy. There we will, we talk about the different loading conditions.

First of all, you have what we call as the loading case 0 condition. This means an empty ship. Therefore, we call it an empty ship ready for operation, means, everything is, the ship is ready for operation, everything is there and that is all, machinery, everything is there and, but none of the loads are there, but machinery is there, the propeller is there, the hull is there. Hull is fully defined, all the structural, all the structural members are there, stiffness, bulk edge, everything is there, deck heel, everything is there, but, and, and the machinery also is there, the equipments are there, but the load is not. This is called as loading case 0. It is called an empty ship; we sometimes call it as the light weight also.

And then, then the next we call it as loading, loading case 1. This is with limited displacement; limited displacement. The meaning of this is, we are now talking about a ship, which has some additional weights in addition to this machinery and all that, we have the crew, we have 1 crew and their personal effects. So, they have, we have the crew and their belongings, then we say 10 percent these.

Remember, these are all fixed rules consumables. By consumables, anything food and water are consumables and anything that you use on ship, anything else is consumable. Whatever you use in, the crew uses, even the engine oil is consumable. So, different kinds of such thing when you, if the total capacity is 100 percent. So, 10 percent of such consumable, these come under the loading case, loading case 1.

Then, we talk about 10 percent fresh water. Of course, it kind of comes under the previous categories, previous headings, previous, it comes under this. Then, we talk about lubricating oil, 10 percent of this. Then, lubricating oil, fuel, then we also say feed water, feed water and fresh water, drinking water.

Then in case of, we are talking about fighting ship, fighter ship, we also talk about weapons, weapons are what we called as ammunitions, ammunitions. Now, we can have 10 percent of everything, we call it as the, the load loading case 1.

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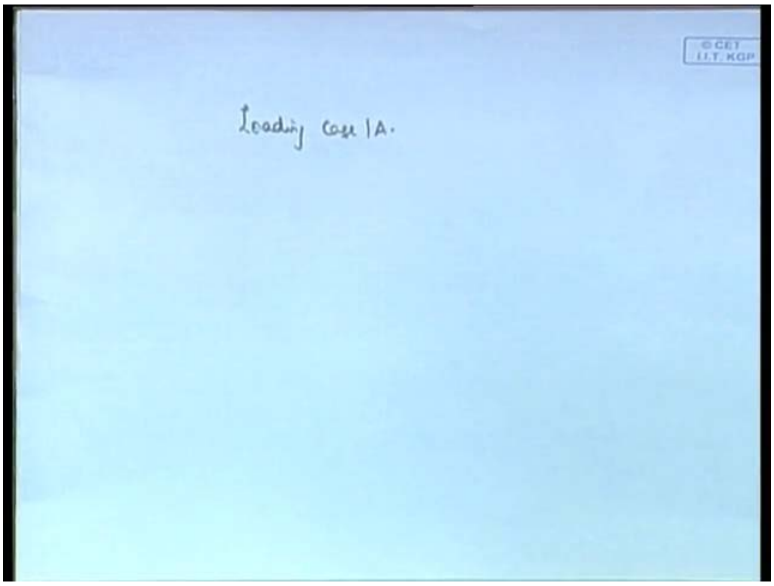

Then, finally, we come to loading case 1A, loading case 1A, this is what the German Navy calls as loading case 1A is the case when you have the rest of the stuff. That is, you have the ammunitions, you have the full water, you have the full ballast water, fuel, lubricating oil, food, ore, grains, whatever you have, everything is called as loading case 1 A ; at that is ends up with your loading.

So, these are different kinds of loading that are these. So, there are a series of rules and regulations that deal with the condition of the ship at various conditions of loading, whether it is loading case 0, 1, or 1A. There are some stability requirements that are to be followed for all these 3. So, that is very important you.

So, this is how the whole stability requirements are done by the navy. So, with this we can stop the stability requirements. In fact, if you will really go into stability requirements, there are much more and it is very vast field. And what we call as maritime regulations is vast topic in itself and entire course in itself.

So, we will just, we will stop with this series of rules. Just remember some of the rules, which are very important and know, that different categories of rules adopted by the different navy, some important things at least you should remember, keep in mind and with that we will stop today.

Thank You.