**Ocean Structures and Materials**
**Prof. Dr. Srinivasan Chandrasekaran**
**Department of Ocean Engineering**
**Indian Institute of Technology, Madras**

**Module - 1**
**Lecture - 6**
**Subsea Production Systems**

Welcome to the sixth lecture on module 1 on the course on ocean structures and materials, which is conducted under the braces of NPTEL, IIT Madras. In the last lectures, we discussed about different kinds of offshore platforms; some of them of fixed type, complaint type, etcetera. In this lecture, we will discuss something on subsea-production systems. It is also an important component in different kinds of offshore structures, when we start designing offshore structures we should have a fundamental idea about different types of subsea production systems.

So, in this lecture will focus on different types of subsea production systems; what are they, what are the different terminologies in subsea production systems, how do we understand them etcetera.

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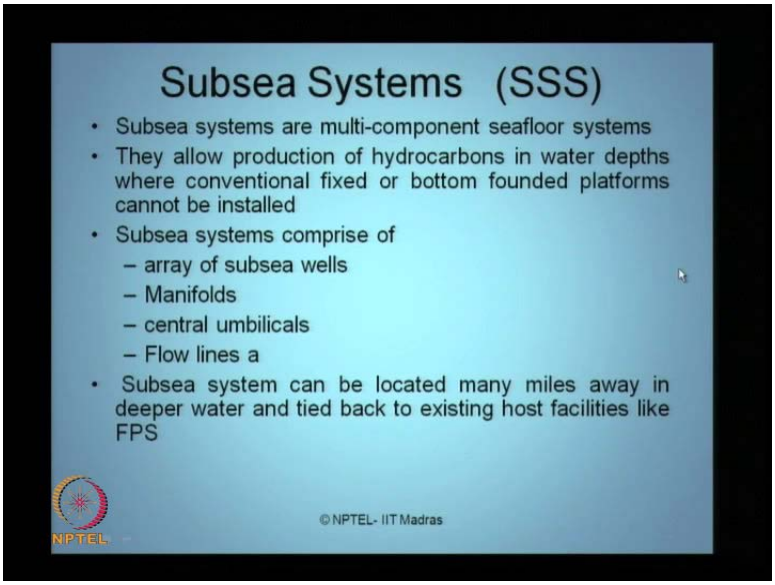


Subsea systems briefly are called as SSS. Subsea systems actually on multi-component sea floor systems; the moment is a multi-component one would like to know the different components that are present in a sea floor system. Essentially let us look at the function

of a subsea system; they actually allow production of hydrocarbons in water depths where conventional fixed or bottom founded platforms cannot be installed. As we understand ladies and gentlemen, all types of platforms cannot be installed in all water depths. There are serious limitations with respect to the type of geometric form of the structure, different types of water depths etcetera.

So, if we have a location, where the conventional fixed or bottom founded platforms cannot be installed then one can go for subsea systems. Subsea system as a set is a multi-component seafloor system; they have different components as listed below. It contains array of subsea wells, manifolds, central umbilicals, flow lines. And a subsea system can be located many miles away in the deeper water and then they can be tied back to the existing host facilities. Now the host facilities, which actually tied on back the subsea systems, which are located many miles away in deeper water, can be a floating production storage system. There may be FPS, they can be FPSO as we discussed in the last lecture.

So, you can have an FPS installed at a distance which can be used to tie on the subsea systems which are otherwise deployed in deeper waters. So, ladies and gentlemen, in natural subsea systems are actually multi if component seafloor systems used for offshore production of hydrocarbon in water depths where conventional fixed platforms cannot be installed.

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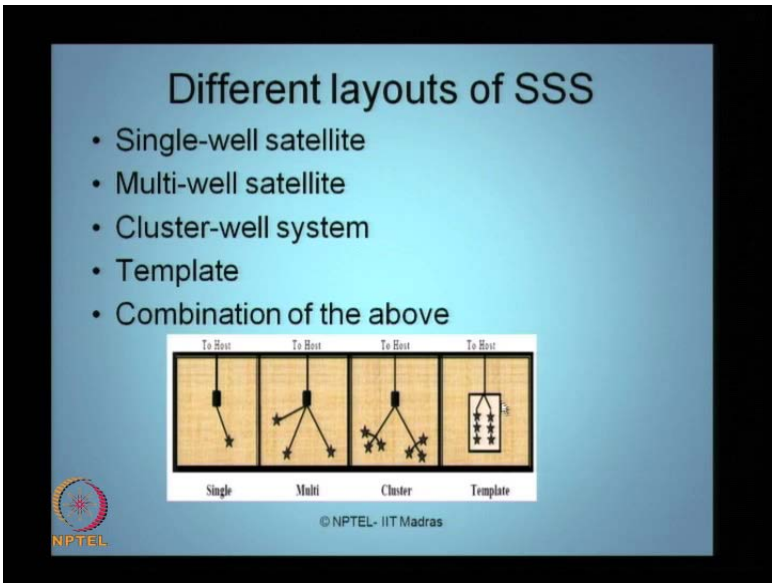

Let us look quickly at different layouts of subsea systems. As you see here in the picture, there can be different kinds of layouts; a single layout where a water well, which can be connected to the host it is a single. Can have a multi well satellite; there can be three different wells or n number of wells ,all can be connected to the host. The host as I said can be an FPS. You can also have what we called cluster-well system. So, wells can be cluster together depending upon the (( )) profile of yield of these wells. So, they can be cluster and then they can be connected to the single host as you see in the picture, or it can be a template structure where you got a template of series a wells connected to one group which can be further connected to the host are obviously can have the combination of all these above. So, subsea systems have essentially four different types of layout, as you see here- single-well satellite, multi-well satellite, cluster-well satellite or a template system.

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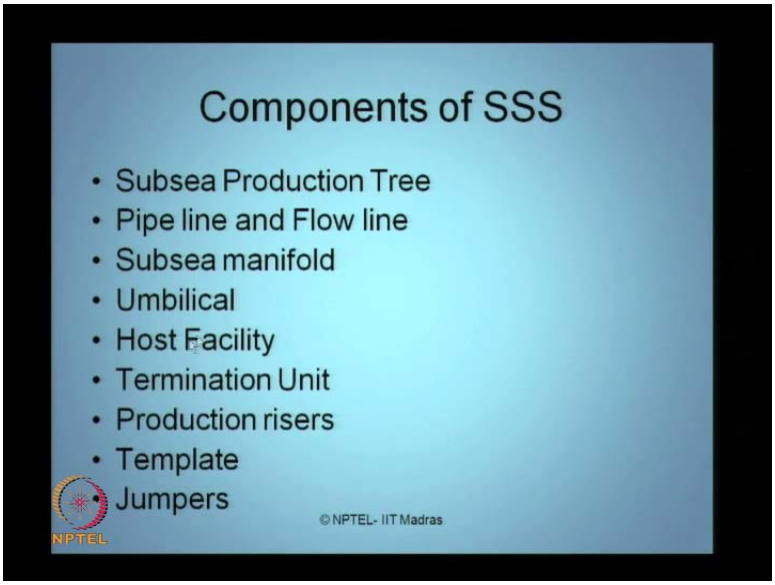


Let us quickly look at each component of subsea system in detail. As I said is a multi-component system contains subsea production tree, pipeline, and flow line, subsea manifold, umbilical, host facility, termination unit and production risers. So we can also have components of template and jumpers attach to it as you see in the slide. So, subsea system contains various components as listed here. Subsea production tree, pipeline and flow line, subsea manifold, umbilical, host facility, termination units, production risers, templates and jumpers.

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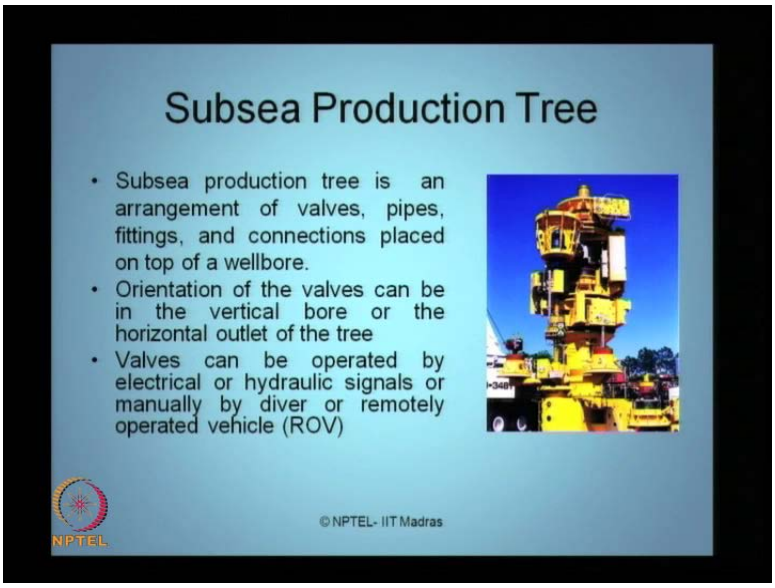


Next topic, we see each one of them separately in detail. So, the picture what you see here is a picture of subsea production tree. Subsea production tree is an arrangement of valves, pipes, fittings, and connections placed on the top of a wellbore. So, we can see it is nothing but an assembly of different appurtenance which would together be arrangement of valves, pipes, fittings, and connections placed on the top of the wellbore. Orientation of these valves, which you put as a connection in a subsea production tree can be in the vertical bore or the horizontal outlet of a tree.

Now the layout of arrangement of the valves can be on the vertical bore or can be on the horizontal outlet of the tree. Valves can be operated either be electrical or be hydraulic signals. Sometimes can also operate them manually by a diver or occasionally can use what we called remotely operated vehicles to operate these valves; they are called ROV.

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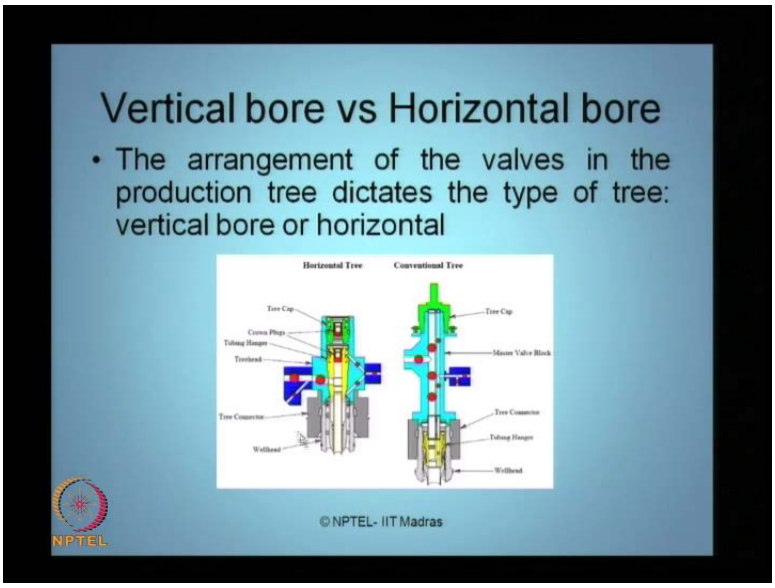


The picture what you see here shows the difference between a vertical bore and a horizontal bore. The arrangement of valves as I just now said in the production tree dictates the type of the tree; it can be either a vertical bore or an horizontal valve. The picture what you see here is, a conventional tree which contains a tree cap on the top then the master well block which is shown in the blue color here, connected to the tree connector we through a tubing anchor which is connected ultimately to the well head.

Similarly, in case of a horizontal tree, you have the tree cap not on the top as a cap, but adjutant on the sides. We can see here, horizontal tree is more latterly spread than that of a conventional vertical tree; that is why this tree is called horizontal whereas this is otherwise called vertical tree. So it is spread horizontally or laterally where it is got a tree cap connected to the well head through a tree connector, and the tree head is here. And the tubing anchor and the crowned flexor as similar to what we see in a conventional tree. So, the dimensions of a horizontal tree can be more compact in height compare to that our vertical tree or a conventional tree, but it needs more lateral space circumferentially to show this tree in your production systems.

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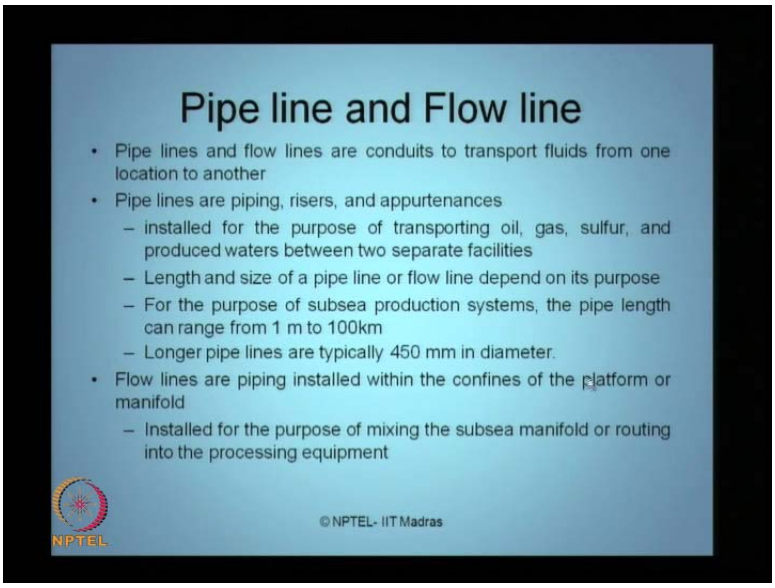


The next component of a subsea system can be either a pipeline or a flow line. Let us try to understand fundamentally the difference between pipeline and a flow line. Pipelines and flow lines essentially are pipes or conduits; they are used to transport the fluid from one location to another location. Pipelines are actually piping, risers and appurtenances, which are used in the production unit. They are installed for the purpose of transporting oil, gas, sulfur, and produced waters between two separate facilities. The length and size of a pipeline or the flow line depends on its purpose. For the purpose of subsea production systems, the pipe length can vary as short as 1 meter to as long as 100 kilo meters. Longer the pipe lines typically they will have larger the diameter up to above 450 millimeter in diameter.

Then what are flow lines? Flow lines are actually piping system again installed within the confines of the platform or the manifold. Whereas, pipelines are installed for the purpose of transporting oil, gas, sulfur between two separate facilities. If you used it within the confines of the platforms, I call that as a flow lines. It is installed for the purpose of mixing the subsea manifold or routing in to the process equipment. So, flow lines and pipelines essentially are systems which are used to transport fluid from one location to another location. If they are spread in a larger area link, I called them as pipelines; if they are confined within the premises of the platform or the manifold, I call them as flow lines.

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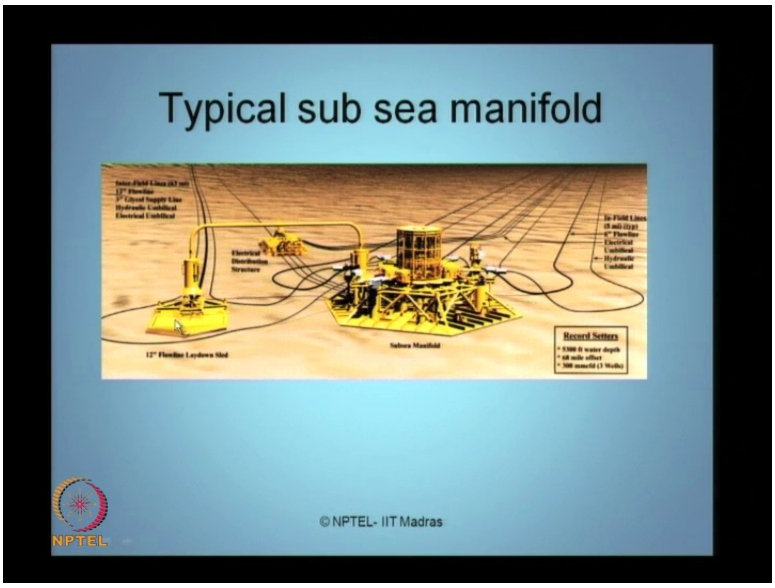


This is the picture, which shows you a typical subsea manifold as you see here. The manifold is connected to 12 inches flow line laydown sled here in the side. As well as the different umbilical cables which have been connecting the flow line laydown the subsea manifold. As I said if it is localized, it is a flow line; if it is spread wide for a longer length, it may be a pipeline.

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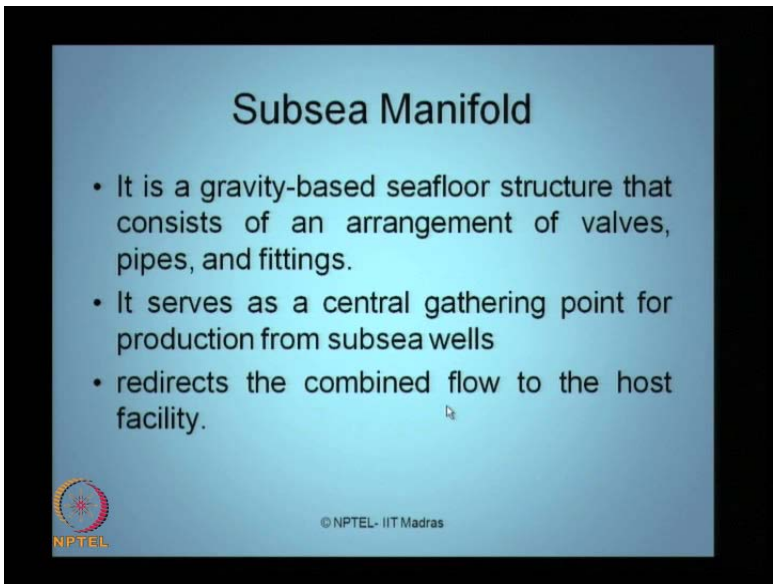


Let us talk about another important component of the subsea system, which is subsea manifold. What is the subsea manifold? It is actually a gravity based seafloor structure.

The moment I say gravity based, you must realize that this rest on the seabed by it self weight; it does not requiring any anchoring device to hold it down to the seabed. So, it is a gravity based seafloor structure that consists of an arrangement of valves, pipes, and fittings. It serves as a central gathering point for production from subsea wells. It redirects the combined flow to the host facility.

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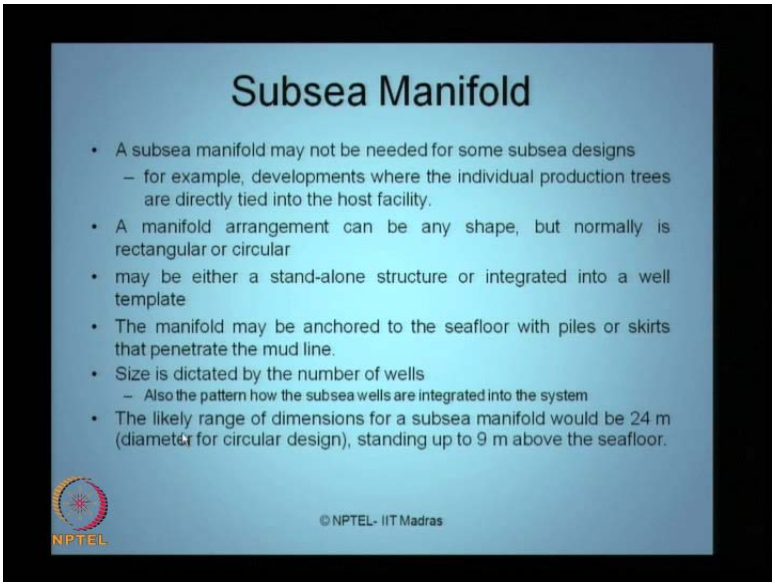


Subsea manifold may not be needed for subsea designs in certain cases. I can give an example, when you talk about developments where individual production trees are directly tied to the host facility, you may not require a subsea manifold at all. A manifold arrangement can be have any shape, but normally it is either rectangular or circular; may be either a stand-alone structure or integrated into a well template itself there is a possibility of a subsea manifold design. The manifold may be anchored to the seafloor with piles or skirts that penetrate the mud line only to improve the lateral stability of the manifolds. Size of a manifold is dictated by the number of wells it is scattering to it; also the pattern how the subsea wells are integrated into the system.

The likely range of dimensions for a subsea manifold would be 24 meter. If you talk about the circular pattern of design and the vertical height can be as high as 9 meters above the seafloor.

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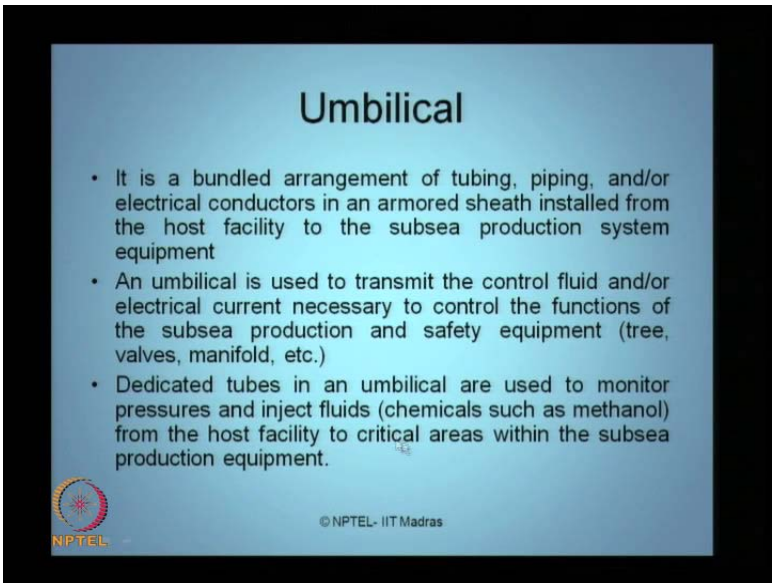


Let us talk about another component, which is umbilical. It is a bundled arrangement of tubing, piping, electrical conductors in an armored sheath; armor means protected, armored sheath, which is install from the host facility to the subsea production system equipment. Remember umbilical's or may be pipes, may be tubes, may be conductors, which are well protected. You may wonder, why in umbilical should be well protected, because this is a tubing or piping which connects the host facility. The host facility can be an FPS, which is connecting the host facility to the subsea production systems equipments.

So, you have to protect from the umbilical's from the lateral environmental loads to which they are subjected too. So, we need a proper sheath thing to protect these two piping's, because there can be reported accidents where the umbilical's have been subjected to severe forces. An umbilical is also used to transmit the control fluid and electric current necessary to control the functions of the subsea production and safety equipments. They can be either a complete manifold tree; it can be valves; it can be manifold etcetera. So, umbilical can be used actually a system which can transmit the fluid or it can be a cable which conduct electric current which is require to control the functions of the production systems.

Dedicated tubes, essentially they are circular in diameter and shape. Dedicated tubes, in the umbilical actually are used to monitor the pressures and injection fluids. As we

discussed in the previous lecture, sometimes the well may be required to be recovered by artificial recovery or enhanced recovery techniques. In such cases dedicated tubes can be used in an umbilical to monitor the pressure inside the well or to inject the fluids. Sometimes, for example, a chemical like methanol can be injected to the well for faster recovery. These umbilical's basically run from the host facility to the critical areas within the subsea production equipment systems.

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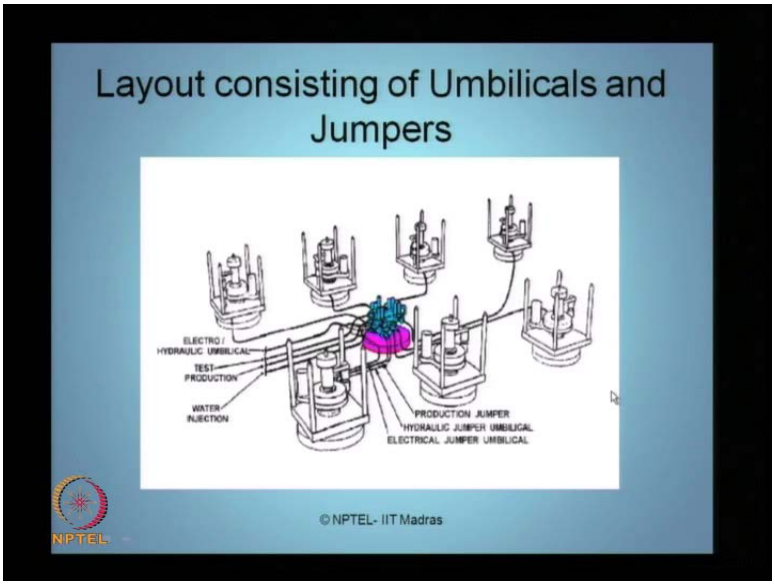


Ladies and gentlemen, now the picture what we see shows the layout of consisting of umbilical's and jumpers. See here, this is actually may production jumper which you see here; this is an hydraulic jumper which is connected to may production jumper followed by which is a separate line which have what I called electrical jumper umbilical. Now as I said to recover the wells we can have water injection into the well, because to enhance oil recovery sometimes injection in to the well may be require. So, we can also have what we call it test production line; a test production line can also be there on sometimes as we said umbilical's can be even electrical conductors which is shown here. So, umbilical is nothing but tubing or piping which connects my host system to my subsea production units.

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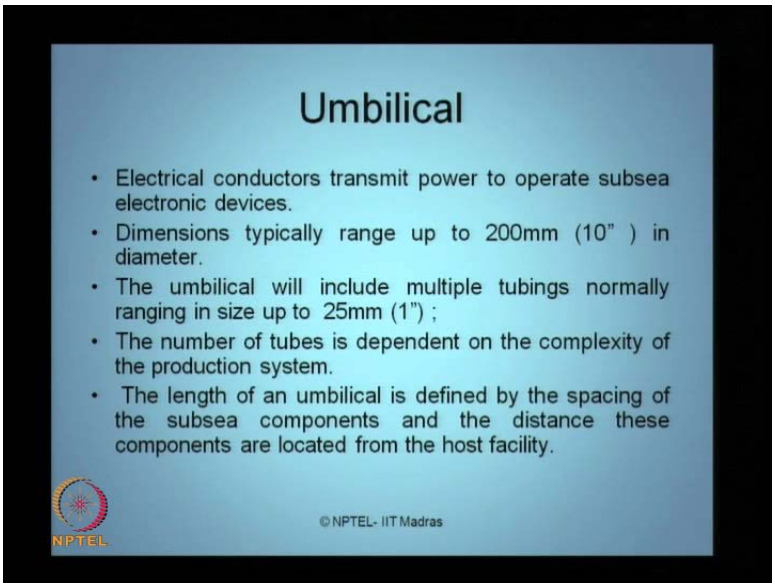


Electrical conductors, which are used to transmit power to operate the subsea electronic devices; can also we host in an umbilical. The dimensions of an umbilical typically range from 200 millimeters in diameters. The umbilical will include multiple tubing's normally ranging from diameter of 25 mm. The number of tubes, which are used in umbilical because as I said umbilical is a combination of multiple tubing's, the number of tubes which are used in umbilical, actually depends on the complexity of the production system, which we are using. The more complexity the production systems are you may require for example, water injection, may require oil injection, sometimes people do carbon sequestration as well. So, unique number of lines or piping's or casings to do this. So in that case, the numbers of tubes hoist in an umbilical will be much more. So, the number of tubes in an umbilical actually depends on the complexity of a production system; however, the size of the tubing's are generally limited to 1 inch in diameter or otherwise 25 mille meters. On the whole, the hole casing or piping will be a diameter of above 200 mille meters. So, approximately in a group of an umbilical they can be above 8, 6 to 8 hoist in an single umbilical.

Then the length of an umbilical actually is defined by the spacing of the subsea components. As I said umbilical is a piping or a casing which is connecting the host system to may subsea production system. Therefore, the length of this umbilical actually depends on the spacing of subsea components. Of course, it is also depends on distance where these components are located from the fundamental host facility. The host facility

may not be always located near the place where the subsea systems are located or exactly vertically above the subsea systems, because subsea systems can be as in deeper waters where the host facility may not be necessarily located in the same depth as that of the subsea systems. Remember subsea systems are production systems, which are used where the conventional fixed the platforms cannot be installed.

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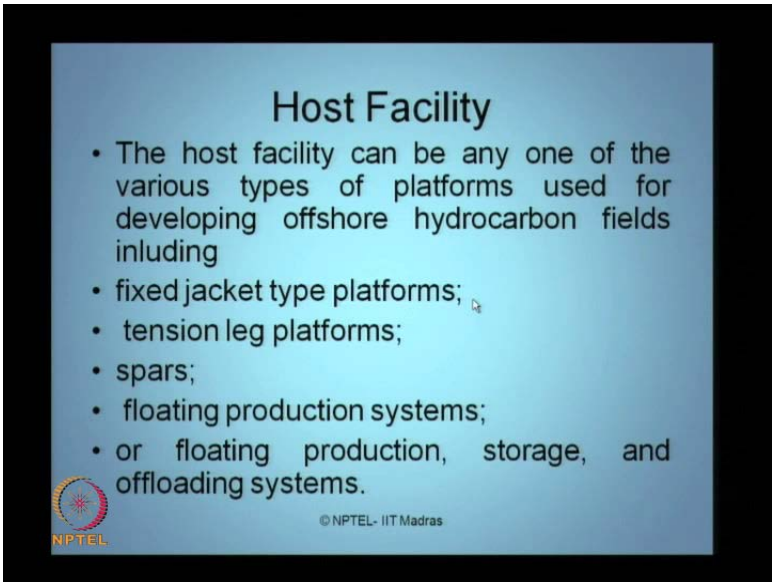


Let us talk about the host facility. The host facility can be any one of the various types of platforms, which are discussed in the previous lectures. These platforms are essentially used for developing hydrocarbon fields, which include. Fixed jacket type platforms we have discussed above this in detail. The Fixed type platform can be have two gravity based as well as team jacket structures, can also have complaint structures like tension leg platforms. We can also have spars as your host facility. Can also have floating production systems which we briefly called as FPS as a host facility. Or can also have what is called FPSO, ladies and gentleman the O in the abbreviation stands for offloading systems. We discussed different types of offloading systems in detail in the last lecture.

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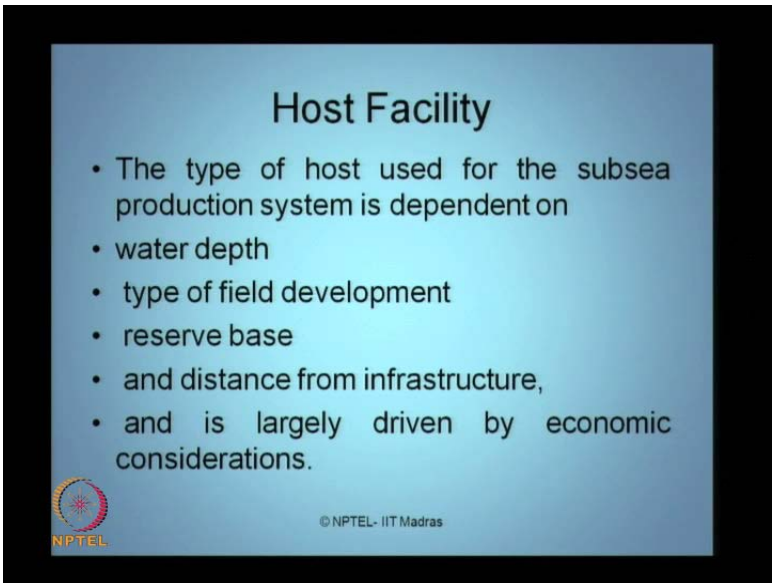


The type of host, which is recommended for a subsea system, depends on many parameters. The host can be anyone of the platform pipes, which we discussed in the last slide; however, how do you select which type of host you got used for what kind of subsea system. What are those factors based on which the host will be selected? Can guess, because now we have enough idea about the different types of host systems that are used for offshore production and drilling. Obviously, as you correctly say, water depth will be one of the primary criteria to select the host.

The type of field development marginal etcetera will also tell you what type of host we must go for. It also depends on how much amount of oil reserve you have in that specific base. And of course, fundamentally how for is a subsea system from the host what we called distance from the infrastructure. Above all most importantly the type of host system essentially is governed by the economic considerations. As you said as you can clearly understood from the previous lectures, it is very clear that all types of platforms are not similar; they are categorically based on a type of water depth. Obviously, depending upon the geometric form and the structural configuration of these platforms, the cost of these platforms, installation, toeing, decommissioning, etcetera keeps on varying fundamentally in a very wide range. Therefore, it depends on what is an economic consideration when you design or select your host system. So, the host selection depends on the fundamental depth of water, the type of the field, the reserved

base, the distance from where you going to hold the host from the production system, and largely and majority wise depends on what are your economic considerations.

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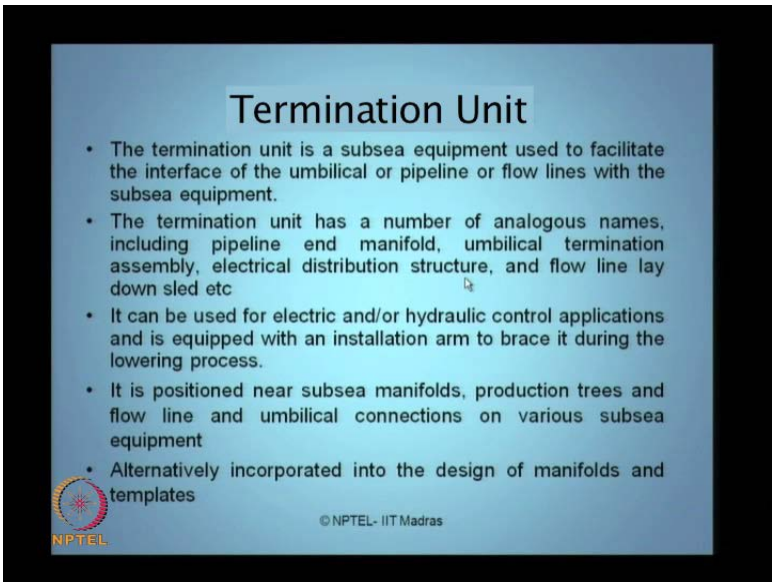


Let us talk about another important unit what we have in a subsea production system which is a termination unit. Termination unit is a component of subsea equipment essentially used to facilitate the interface between the umbilical or a pipeline or a flow line with the subsea equipment. See obviously, you cannot directly connect a cable or an umbilical or a piping or a casing or a pipeline or a flow line, ladies and gentlemen I want to you understand clearly the difference between the pipeline and the flow line. Pipeline is fed for a larger area; flow line is within a manifold or within the premises of the platform.

So, when you are trying to connect either an umbilical or a pipeline or a flow line to a subsea equipment system, you need a piece which is call as a tailor and piece which will connect which will fix these components of the subsea system to that of the subsea equipment. So, that tailor piece or the end piece is what we called termination unit. The termination unit has many analogous names is given in the literature. Sometimes people callthem as pipeline end manifold; people address them as umbilical termination assembly; people also called them as electrical distribution structure; sometimes people address it as flow line lay down sleds. Remember ladies and gentlemen, few slidesdown in the line we see a photograph where the flow line lay down , which is connected as a

termination unit to that of on subsea equipment system. So, the name only differs, but the function is the termination unit is actually a tailor piece or end piece which connects the umbilical or a pipeline or a flow line to that of the subsea equipment in general.

It can also be used for electric or hydraulic control applications. Thay can also be used for as an termination unit for electric or hydraulic control applications. It is equipped with in installation arm to brace it during the lowering process, because you got to fundamentally do this installation termination unit very carefully, because the termination unit is one of the vital piece which connects the end of this line to that of the subsea equipment. So, it comes with a bracing installation arm to brace it or tie it very carefully lay down while during the lowering process. It is a position near the subsea manifold, usually the location of the termination unit as the name suggest it is as close as possible to may subsea manifold, production trees, flow lines and umbilical connections on various subsea equipments. Alternatively, it is also incorporated the design of manifolds and templates itself.

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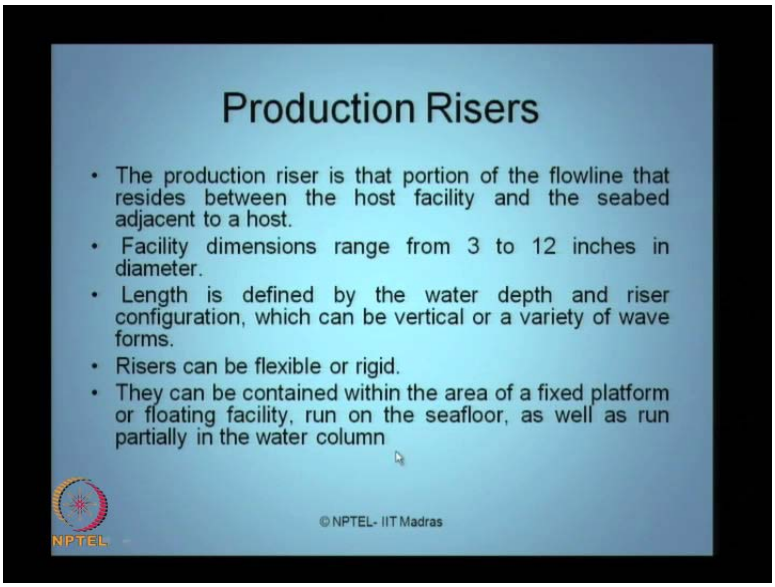


Let us talk about another important component of a subsea system, which is production riser. The production riser is that portion of a flow line, you must understand what you mean by a flow line; it is different from a pipeline. The production riser is a part of the flow line that is located between the host facility and the seabed adjacent to the host. Host facility can be any one of the types of platforms, which we have learned by this

time. Sea bed adjacent to the host is the location between which the production riser will be located.

The facility dimensions of these risers range from 3 inches to 12 inches - mostly circular in shape. Therefore, these are diameters of the production risers. The length of riser actually defined by the water depth and the riser configuration, which will be a vertical or variety of wave forms have been used as p-lay, x-lay etcetera. So, the length is defined by the water depth where you are doing the production or drilling. and the riser configuration what you are planning to use for the production riser. The risers can be again alternatively of two types; we can have a flexible riser, can have rigid risers as well. They can be contained within the area of the fixed platform or the floating facility or they also can run on the sea floor as well as run partially the water column also.

So remember ladies and gentlemen, analysis and design are production risers is one of the most complicated task what we do in the analyses of offshore structural design, because they will be subjected to differential kinds of environmental forces and they are as complex as that of the platform themselves. So, production risers can be confined within the plate form area; it can be also run along the sea flow or as well as they can run partially water in column as well. So, you have to designed these risers for all possible wave loads, current loads, seas covers bed forces, earthquake forces, settlement forces etcetera, because pipe line or production risers are very long in length compared to the diameter. So, they have what is call the slenderness ratio problem in the design.

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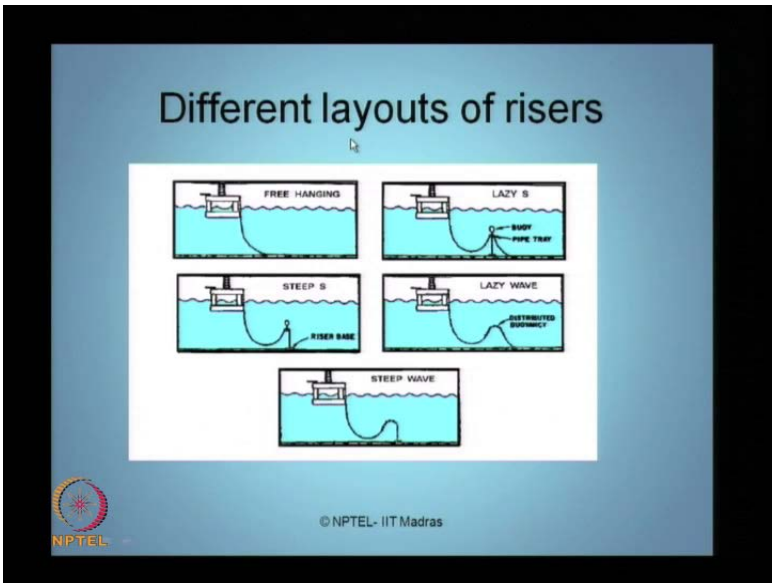


These are different layouts of the risers what we see here. I can have a riser which is freely hanging from the host facility, can also have a layout call LAZY S. This layout is typically named as a LAZY S, you may wonder how do a hole this riser vertically up over this point. I use a buoy here, the buoy will start floating at this location, can connect it here the use of here what we called as a pipe tray to connect one end of the production riser. And I call this layout of geometry as LAZY S layout. I can also have what we call a STEEP S layout, where I will do the same methodology then hold it down to the raiser base. I can also use what we call as a lazy wave form which is actually attained by distributed buoyancy, or I can also have what is called a steep wave form of these risers. So, the pictures what we see here are different types of layouts of risers which have been used in the literature.

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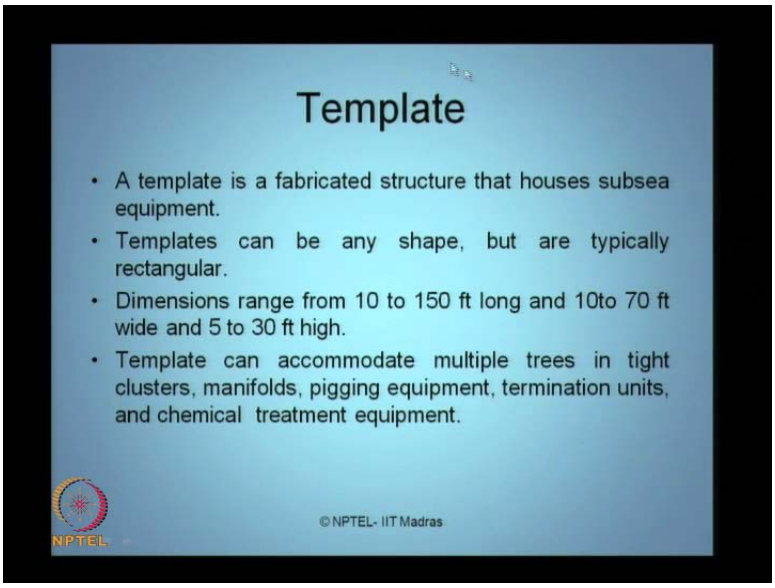


The other component what we see in the subsea system is what we called as a template. What is the template? Template is the fabricated structure that houses the subsea equipment. The subsea equipment is house on a fabricated structure we called that by a specific name called template. Template can have any shape, but typically people used commonly rectangular type templates. The dimensions of the template vary from 10 to 150 in feet in length, and 10 the 70 feet in width and 5 to 30 feet height. Template generally accommodates multiple trees in tight clusters, manifolds, pigging equipment - pigging equipment is used when you what the production risers choke because of some flow problems. Termination units we have already seen couple of examples of different kinds of termination units, which are put at the end piece with that of the pipes and the manifolds, and the chemical treatment equipments. Chemical treatment equipments are generally required to want to perform what we called injection of wells for improving the recovery, or what we called enhanced oil recovery templates. So, template can accommodate multiple trees in tight cluster; it can contain manifolds, pigging equipments, termination units, and chemical treatment equipments. So, the assembly of entire thing of these dimensions is what we called as a template, as a fabricated structure which is assign as the name template in offshore engineering.

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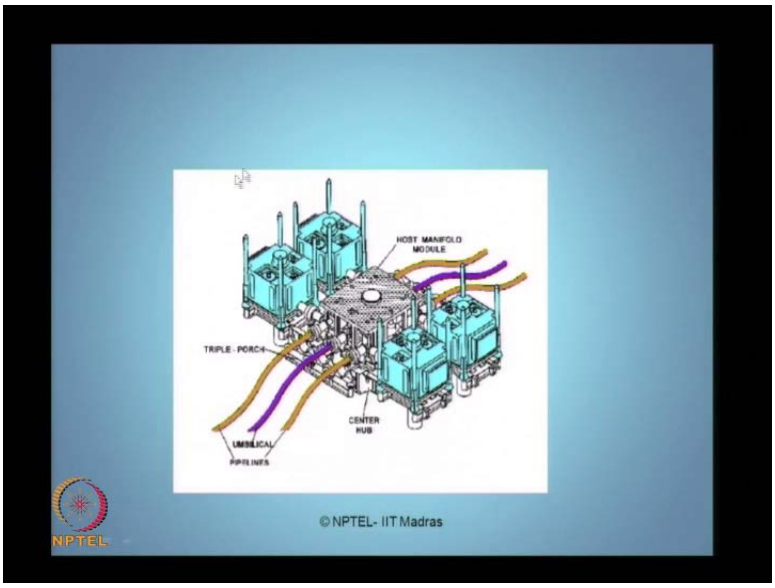


We can see a typical figure of a template which contains umbilicals. Umbilicals of given different color; this can be either different conduits, can be even pipes, can also have what we called pipelines which are given in different color. We have center hub, which connects the host manifold module to that other different facility.

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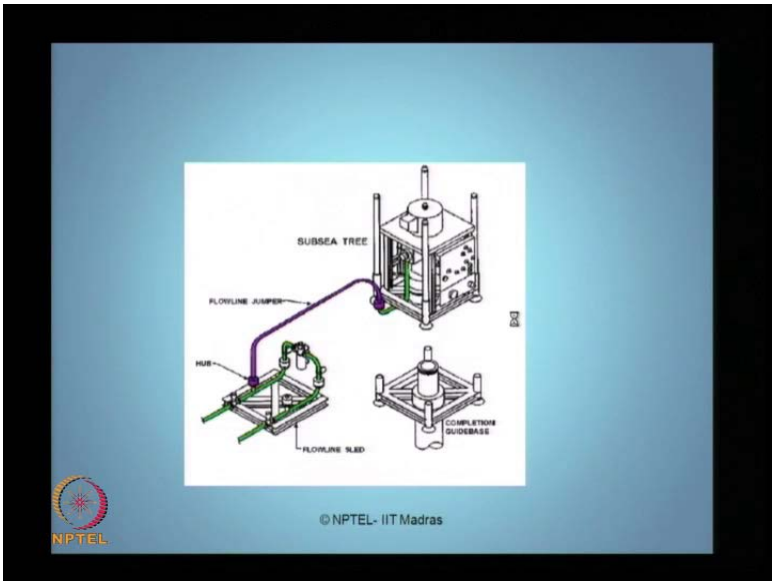


The other figure shows how the subsea tree is connected to the hub using what we called a flow line jumper.

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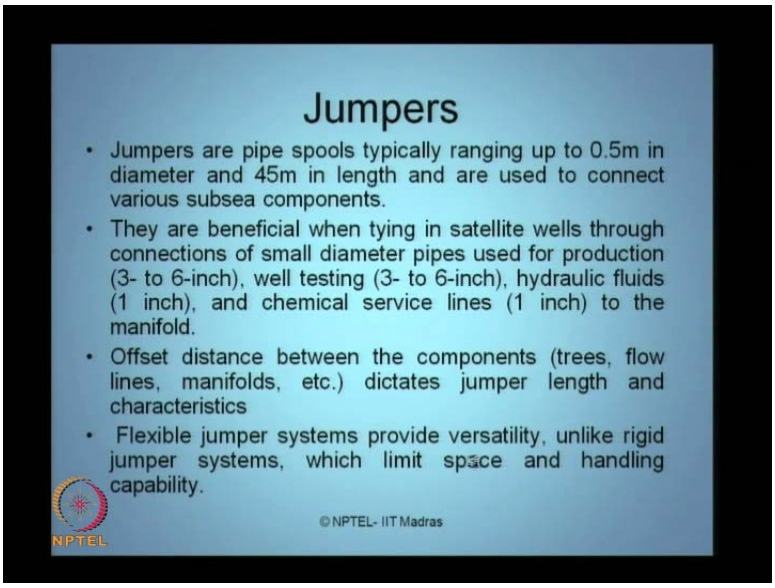


Then the question comes in mind is what are jumpers? Jumpers are pipe spools typically ranging up to 0.5 meter in diameter and 45 meter in length and are actually used to connect various subsea components, as you saw in the previous picture. They are beneficial when tying in satellite wells through connections of small diameter pipes which are used for production. The diameter can vary from 3 to 6 inches, well testing line can vary from 3 to 6 inches, hydraulic fluids can vary to the diameter of one inch and the chemical service lines can vary to the diameter of one inch to that of the manifold.

Offset distance between the components. What are the components of subsea, we can says trees, can say flow lines, can say manifolds etcetera. The offset distance between these components actually govern the jumper length and the design characteristics of the jumpers. Flexible jumpers are one of the varieties of jumpers which are provided. They give high versatility, unlike rigid jumper systems, which limits the space and handling capacity. So, flexible jumper systems are preferred in deep water offshore engineering where unlike rigid jumper systems they do not limit that space and handling capability.

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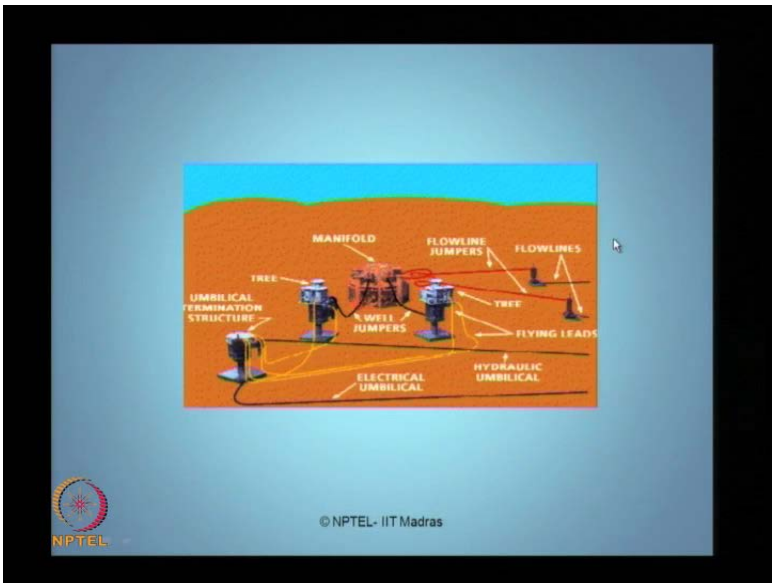


Now, the picture shows what the different types of jumpers are. You see here, this manifold, there are these well jumpers what you see in the black color here, What I am called in these as a tree. These are all the flying leads, which are connecting the tree each other. We can see the blue line here can be a piping or a casing, I called these as electrical umbilical. Now this carries fluid, I called this is hydraulic umbilical. These are all flow lines; these are all flow line jumpers and so on. So, you must now understand a typical layout of subsea system .What are they important components in a subsea system like a manifold, like a flow line, like a pipe line, jumper, what are trees, what are umbilical's etcetera after understanding this lecture.

Thank you very much.