Recent works in the Construction of Marine Pipelines for Desalination Plants

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Introduction

In recent years, the Consulting Company Increa has been involved in the design and construction of the pipelines for several desalination plants. These works include sea-weather studies, diffusion, mechanical studies of the pipes, constructions procedures, etc.

Special care has been taken in the study of the procedure to sink these pipes, with their enormous size. In this presentation, we will mainly focus at the sinking procedure of these pipes, describing our works to place them on the seabed, for the following desalination plants:

-Valdelentisco- Murcia- (Spain)

For this desalination plant, Increa was involved in developing several Projects, including the Constructive one. The project contained the following main design tasks:

Design of the intake system:

The intake system for the desalination plant in Valdelentisco was comprised of a series of pipelines with a total length of 1.450 m. The pipeline is a helicoidal high density polyethelyne (PE80) tube, with an interior diameter of 1.800 mm and varying thickness and rigidity. A tunnel with polycrete tubes was also constructed. The pipeline reaches a maximum depth of 26m and will transport a maximum flow of 4,62 m^3/s.

Included in the design is the intake tower. The tower is a cylindrical reinforced concrete structure with four cage filters.

Design of the discharge system:

The discharge system, also made of helicoidal high density polyethelyne (PE80) tubes, measured a total length of 1.260 m. The

discharge pipeline is located parallel to the intake pipeline, with a maximum depth of 22,5 m. It was designed with an interior diameter of 1.500 mm, of variable thickness and rigidity, and exposed to a maximum flow of 2,32 m^3/s.
The diffuser is composed of 10 risers spaced 6 meters apart.

Photo 1: Sinking using flotation devices: Valdelentisco

-Skikda (Algeria)
In Skikda Algeria Increa developed the designs for the complete constructive project for the pipeline system. The pipelines were designed using helicoidal PEAD tubes, consisting of an intake system with an interior diameter of 1.800 mm and a discharge system of an interior diameter of 1.500 mm.
In addition, Increa designed the intake tower and a diffuser for the brine.
Intake pipeline:
The intake pipeline is a total length of 1.171 m. The service of the pipe will be subjected to a maximum flow of 2,53 m^3/s and is located at a maximum depth of 18 m.
Discharge pipeline:
The discharge pipeline is a total length of 676 m, subjected to a maximum flow of 1,34 m^3/s and located at a maximum depth of 9 m.

Amongst other aspects, the Project included the study of the system with respect to seismic forces.

Photo 2: Sinking using flotation devices: Skikda

-Beni-Saf (Algeria)

The constructive Project for the pipelines of IDAM in Beni-saf involved the following aspects:

Intake pipeline:

The intake pipeline for sea water is made of High density polyethelyne (PE80). The interior diameter measures 2.400 mm and the total length of the pipeline 1.200 m. The pipeline is located at a maximum depth of 18 m, and will be subjected to a maximum flow of 5 m^3/s.

Brine discharge pipeline:

The discharge system is made also of high density polyethelyne (PE80). The interior diameter is 1.800 mm, with a total length of 1.574 m. The depth is approximately 8 m, and will be subjected to a flow of 2,68 m^3/s.

Pumping of water on land:

The system to drive water from the pumping station to the desalination plant was designed with a pipeline measuring 1.800 mm in diameter, total length of 831 m, and subjected to a maximum flow of 5 m^3/s. This pipeline is made of Polyester reinforced fiber glass (PRFV S5000).

Photo 3: Introduction of the pipes in the sea: Beni-Saf

-Honaine (Algeria) and Mostaganem (Algeria).

Increa is cooperating in the design of the pipes and their protection, whose sizes are very large.

Construction procedure for sinking the pipes

Justification of the construction method

Traditionally, for the installation of PE pipelines of medium or small diameters (<1500 mm) to the sea floor, we utilize the method of “controlled sinking by progressive flooding” of the pipeline. This method can be executed without difficulty for these diameters, always

when the forces generated in the pipeline throughout all of the phases are analyzed with great detail.
New desalination plants have high production capacity and they need the use of pipes of large diameters for getting water from the sea and for discharging brine back into the sea.
With the development of these pipelines of large diameter as well as the more frequent use of helical tubes, it was necessary to develop new procedures that permit the optimization of the geometry of the tube and thus minimize costs of the job. In developing this method we have taken into account that in the majority of cases, the installation phase determines the mechanical properties of the pipeline (principally the wall thickness and inertia) because when in service, the forces produced are much smaller.
Using flotation devices to help the sinking of these types of pipelines resolves all these problems without the need for extreme means of construction.
Thanks to the execution using this method, the pipeline suffers lesser stresses, which produces a greater margin of safety. Having this greater margin of safety facilitates the maritime operations, eliminating risks and makes simpler management of the operations possible.
This method makes the need to apply longitudinal tension forces to the tube unnecessary, which simplifies the process of pipeline installation, especially when realizing joints on the sea floor.
Being a method that greatly reduces the demand on the pipeline due to the control of submerged weights (ballasts) and upward lifts (flotation devices), other factors should be taken into account, such as the residual floatability of the overall structure, the loss of volume in the flotation devices due to sinking, the weight of the singular elements etc.
In this presentation, we will describe only the forces generated during the flexion of the tube in a vertical plane, without including the forces that could be generated by currents or other horizontal forces. Although we will not include these forces in our presentation, due to the fact that this process attempts to reduce the forces due to vertical flexion (due to less floatability, and further more, less upward pull), it should be taken into account because they could end up being more demanding. Therefore, other factors that begin to have more importance, such as currents and wind, would need to be analyzed. As

a result, it will be necessary to adequately control the position of the pipeline, both vertically and horizontally.

Description of the construction method

As we have already said, the use of flotation devices is needed. They can be rigid or flexible. In the first place, its structural integrity should be guaranteed, insofar as the exterior pressure varies. Secondly, the variation of their volume should be taken into account, since it reduces as the exterior pressure increases. Pressurization of the flotation devices is a good way to avoid this problem.

During the transport of the strings of pipes, floating on the sea, it is essential not to force the position of the pipeline in order not to produce excessive tensions.

In addition, it is indispensable to prepare a launching slope for the introduction of the pipes in the sea, from the land area where they are welded and ballasted.

Over this launch slope we will weld the pipes and place the ballasts. The profile should also be carefully studied, as bending of the pipe should also be controlled during launching.

The sinking process with the help of flotation devices is realized in two different stages, which are explained in the following sections.

First Stage:

The first stage consists in the complete and progressive flooding of the pipe while it hangs by the flotation devices (which stay on the surface of the water). At the beginning of the flooding process (and consequently the sinking of the pipeline), the cables and the flotation devices begin to work, pulling up on the pipeline from the surface of the sea. The forces produced in this stage will be smaller the shorter the cable length is. At the end of this stage, once the pipeline is completely full of water, it remains in a horizontal position, completely suspended by the flotation devices.

We can divide this first stage into the following phases.

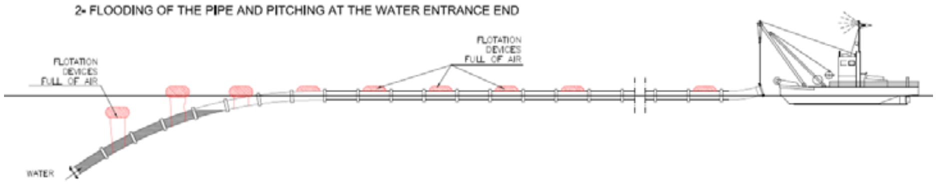
Phase 1. – The pipeline is floating on the water surface, full of air. The union of the pipeline to the flotation devices by slings is realized, although they are not yet working.

1- PIPELINE RESTING ON THE SEA SURFACE WHILE PLACEMENT OF FLOTATION DEVICES

The flotation devices are placed with uniform spacing, except for specific ones, situated in areas where the pipeline suffers additional weight at specific points, such as the flanges located at either end of the tube. Also, it is advisable to place an extra flotation device (with a minimum sling length) at the end where will begin the sinking, in order to correct the possibility of excessive inclination of the pipe, in which case it will begin working when the pipeline begins to descend into the water, receiving the initial forces.
In addition to these flotation devices, it is also recommendable to have precautionary devices in the case of any type of accidental damage or defects in pressurization.

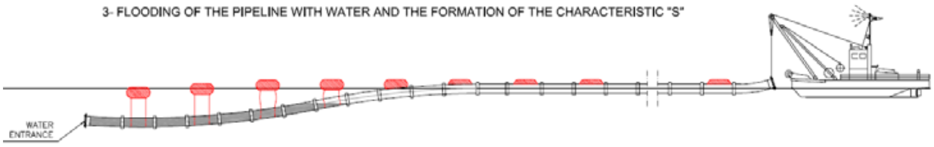
Phase 2. – The pipeline is flooded by opening the water valves at one end and the air valves at the other. When the amount of water inside the tube is sufficient, the first flotation device will begin to sink, generating a vertical reaction which reduces the bending moments with respect to the previous instant.
The water valves should never be opened at both ends because it would generate an air bubble in the center of the tube which is difficult to expel.

2- FLOODING OF THE PIPE AND PITCHING AT THE WATER ENTRANCE END

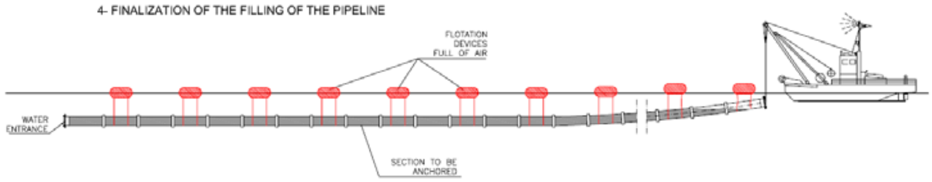


During this phase, it is recommended to situate a crane at the end of the pipe opposite to the end being sunk. The crane is then able to slightly raise the pipe above the sea surface level, in order to avoid the accumulation of water at this point, which could provoke undesired sinking at this end.
The tube acts as a cantilever in the way that one end is loaded downwards, and the rest loaded upwards.

Phase 3. –There arrives a moment in which the pipe appears horizontal in the initial zone, forming the classic “S” shape and advancing in a way which augments the length of the pipe flooded. The “S” shape and the height stay constant, resulting in only a horizontal displacement. The same thing happens with the loads and the bending moments.

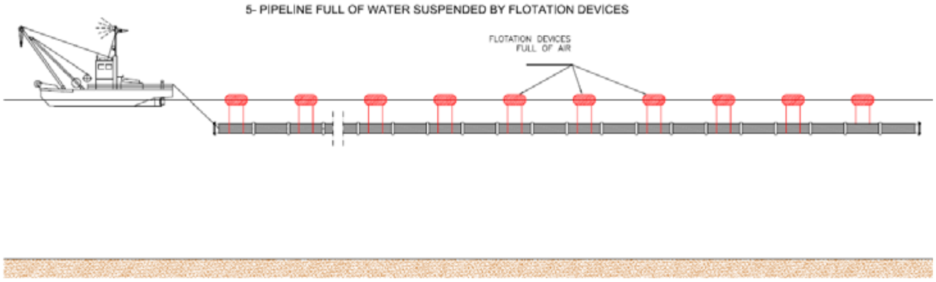


Phase 4. – As water continues to enter the pipe, the length visible on the sea surface reduces until the entire pipe is no longer visible. The pipe acts as a cantilever with one end loaded upwards and the end closer to the sea bottom loaded downwards.



Phase 5. – Through the flooding process, the tube remains hanging by the flotation devices, resting a few meters from the surface, without producing very large forces.

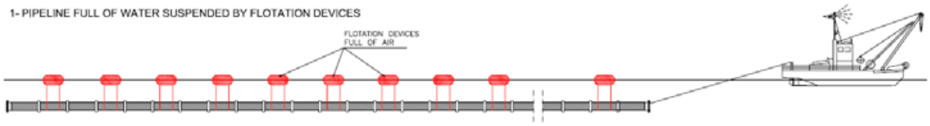
This is the moment to verify that the residual floatability is what was expected and that all the flotation devices are working perfectly. In the case of having to use precautionary flotation devices and after checking they are not necessary, they should be removed before starting the next stage.



Second Stage

Once the pipeline is in a horizontal position and straight, hanging by the flotation devices, it passes into the second stage, which consists in the progressive flooding of the flotation devices, starting at one end and continuing along the pipeline until the entire tube rests on the sea floor.
In this description, we will discuss the flooding of the flotation devices, or the exhaustion of them, referring to the same phenomenon, by which the said flotation devices lose their lifting capability, or floatability. If the flotation devices were rigid, in reality they will be flooded. If they are flexible, they will empty themselves of air, or in other words, proceed until their exhaustion.
Since, in this stage, the flotation devices are going to descend to a greater depth, it is important, in the case of flexible flotation devices (balloons or similar) to maintain their volume as they descend to the sea floor. To do so, they should be duly pressurized. Maintaining a supply line of pressurized air is a good way.

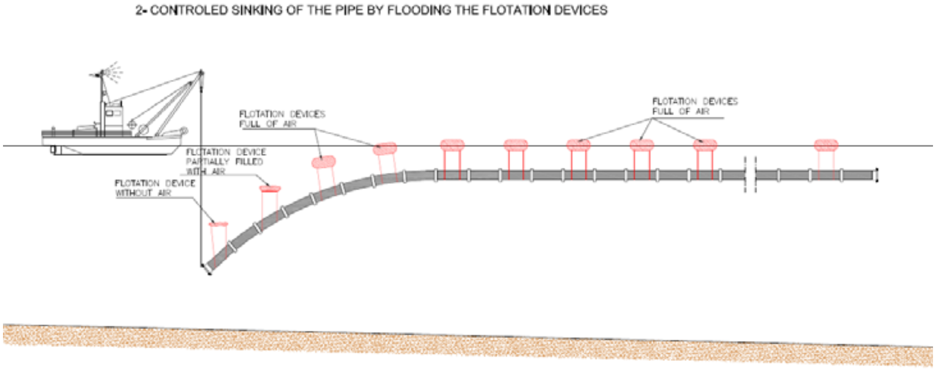
Phase 1. - Corresponds to the last phase in the first stage. The pipeline remains straight, hanging from the flotation devices, a certain distance from the surface, and most importantly, without forces, except for those due to the discontinuity of weights (ballasts) and lift force (flotation devices). This arrangement of "continuous beam" produces depreciable forces.
The valves for the entrance of water to the tube should be open so that the interior and exterior pressure of the water is equal.



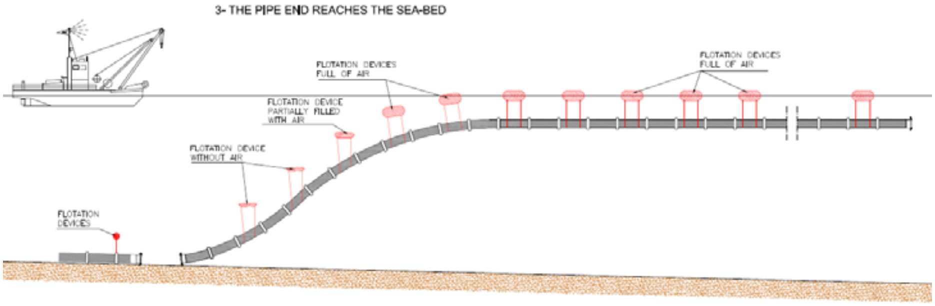
Phase 2. – Begins the second phase of the process: the resting of the pipeline on the bottom of the sea. When the first flotation device is flooded, the pipeline begins to descend towards the sea bottom from that end, while the other end remains at the depth marked by the length of the slings. As the flotation devices continue to be flooded, the pipeline descends.

The flotation devices on the surface of the water (though full of air) begin to sink and disappear from the sea surface. So the diver is always executing the operation of emptying out the devices at a certain depth.

With the object of reducing, even more, stresses in the tube, the flooding of only a portion of the flotation devices in a progressive form can be considered (for example, only flooding one of every three devices).

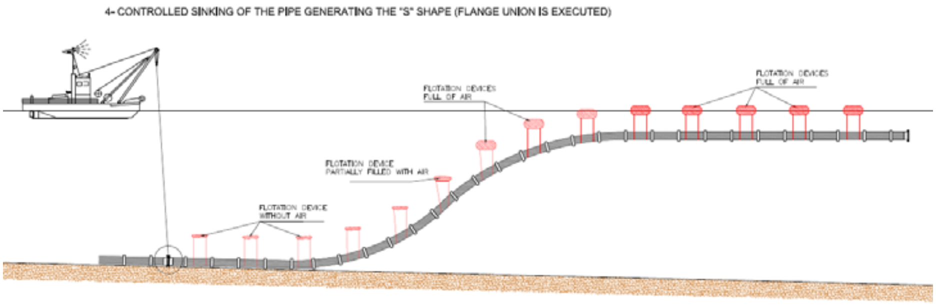


Phase 3. – When a sufficient number of devices have been flooded, one extreme of the pipeline touches the bottom of the sea. In the case of flexible flotation devices, the individual and progressive flooding of each device is necessary, so that the sinking is controlled with ease and is not unnecessarily accelerated.

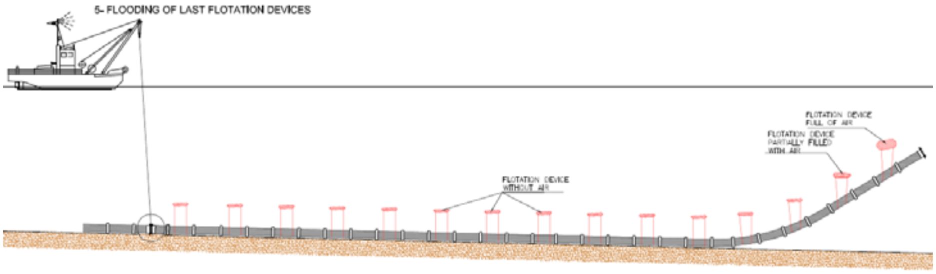


Phase 4. – As the flotation devices continue to be flooded the classic "S" is generated (see in the following figure), and continues advancing until the complete sinking of the pipeline.

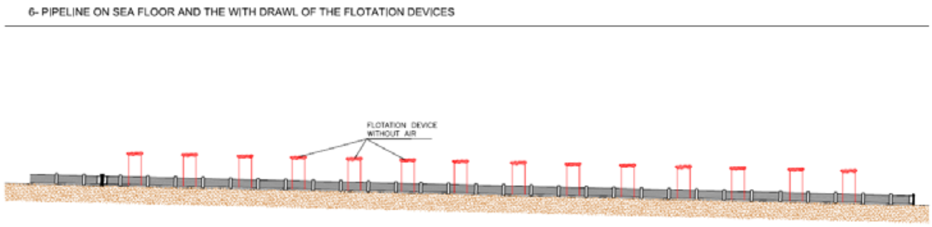
It is in this phase when the union of the union to the preceding pipeline should be carried out on the floor of the sea. Last works on the joint can be executed along the end of this phase and phases 5 and 6.



Phase 5. – There arrives a moment in which so many of the flotation devices have been flooded that there are no left on the surface, and only the last few are left to flood, which still pull up on part of the tube.



Phase 6. – The pipeline remains supported on the bottom of the sea. Afterwards, all the flotation devices are untied and brought to the boat. The sinking of the pipeline is now completed.



<u>Recommendations</u>

For the first stage

Since the "S" is very smooth, the slopes that the pipeline forms are very small. If the ballasting of the tube is very low, we recommend that a crane lifts the end which is to be submerged last (without creating a slope which allows water to be released from the other end), which serves us as a measure of control to make sure that the aforementioned end does not descend excessively and thus avoid the entrance of water thus allowing for air to exit well through this extreme.

The relationship between the diameter/thickness of the tube and its flexibility require reflection on the phenomenon of buckling due to exterior pressure.

Due to the great interior volume of these tubes, and the great floatability associated with it (small percentage of extra weight due to ballasts), if there exists seasonal limitations (due to the short windows of good weather, without waves), it is recommended to use a water pump that increases the velocity of the water entering the tube, and

thus facilitate the sinking during this first stage. In this way, it is possible to introduce pressurized water into the sinking zone to speed up the sinking process.
Once the final equilibrium situation approaches, it is recommended that the screws and the closed flanges are taken off, thus avoiding having to do this work at the end of the process, after the second stage, in deep water.

For the second stage
The stresses produced in this second stage can be alleviated by lengthening the cords of the flotation devices, or otherwise stated, realizing the first stage at a deeper depth. This however, in exchange, increases the forces produced in the first stage.
It is important to control the residual floatability of the whole structure, since with less residual floatability (for the same submerged weight of the structure, in the zone with flooded flotation devices), less forces in the second phase.
Thanks to this method of sinking the pipeline when it is completely full of water, with the valves completely open, the possibility of producing buckling in the tube due to exterior overburden pressure is discarded, since at all times there is equilibrium between the internal and external pressures.

Conclusiones
The sinking of pipelines in the sea is a delicate operation, whose complications increase with its diameter.
The traditional system of sinking controlled by progressive flooding, which we have applied in numerous projects, should be replaced by others if we want the forces reduced and want to optimize the pipeline.
We consider that the method which we have explained in this presentation (sinking in two stages, with the help of flotation devices) fulfils all the requirements which should be expected of any constructive process in the sea: simplicity, safety, reliability, economics, and speed.
Fine tuned calculations of all the phases are essential to achieve the adequate safety margins. It is better to spend additional efforts in the engineering phase than to waste money on designs over dimensioned or ruptures and repairs of the pipeline on the job.

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