# ADVANCEMENT OF TECHNOLOGICAL PROCESSES OF PIPE LYING USING ELEMENT-BY-ELEMENT TESTING.

**Abram Teplitskiy**, **PhD, Scientific Consultant,**
**Roustem Kourmaev**, **President**
**Advanced Technologies International, Inc., Richardson, TX, USA**
**tepl@sbcglobal.net**

In our previous two articles about TRIZ application in construction we considered examples of 40 invention tricks **(1)**, and main methods of solving technical contradictions in construction **(2)**. In the present article we would like to follow up development of a new technological process for construction industry, using different type of TRIZ tools and its combinations. As we used to do in our previous articles, we'll use for illustration mostly our own inventions taken from real "inventing" life.

As basis for this article we selected pipeline technology. We would follow up the process of developing what we called **element-by-element testing of pipelines** in process of their mounting. Technological processes of pipe laying include, but not limited with digging a trench and doing other earthwork for placing engineering equipment like lift station, etc, mounting pipes on project depth, connecting pipes in a pipeline, testing mounted sections of pipeline and technological equipment, backfilling the trench, and provide other finishing operations according to the project. In most cases named processes usually are carrying out step-by-step. Because of this way, time of fulfilling the complete job is a sum of times necessary for doing all technological operations **(3).** Analysis had shown that if technological processes of pipe mounting and pipe testing could be carried out in parallel, it would reduce technological time necessary to bring the pipeline to working condition. Based on this concept, we developed some technologies of combining processes of pipe laying and pipe testing.

Initial ideas for developing such a "technological merger" came from experiments with plugs for testing pipelines. Plugs contained built-in rubber gaskets, which could be axially compressed, and due to rubber deformation they plugged the pipe opening. During experiments we tested plugs under increasing pressures, and we found that starting from some pressure plugs started to move inside the pipe. The **serendipity** support, based of this observation, brought us an idea of a new type of plug, which we called **moving** plug. The scheme of initial step of combined laying and testing pipelines, based on moving plugs, is shown in the Fig.1.

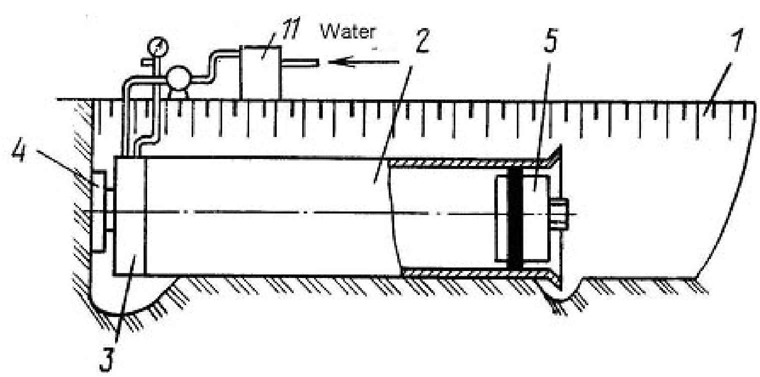

**Fig.1.**
**Public Domain – SU Patent #1,571,156.**
**1-trench; 2 – initial pipe; 3 – end plug; 4 – support;**
**5 – moving plug; 11- water pump.**

After the moving plug and pump equipment are set up, the second pipe is placed in trench and mounted to first one using any type of technique. Using the water pump 11, the water pressure inside the pipes should be raised up to testing requirements. Under this water pressure the moving plug 5 started to move through the second pipe 10 (Fig.2) with constant speed.

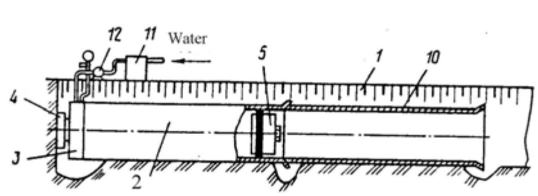


**Fig.2a.**

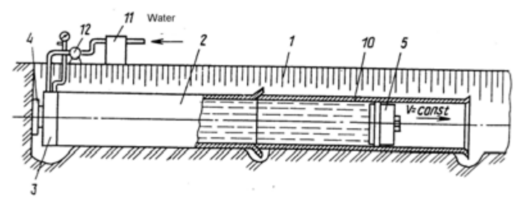


**Fig.2b.**

**Public Domain – SU Patent #1,571,156.**
**1 – trench, 2 – first pipe, 3 – end plug, 5 – moving plug,**
**11- water pump, 12 - manometer**

Intensity of water flow (productivity of water pump) could be determined by formula **(3)**:

$$\mathbf{Q} = \frac{\mathbf{4\pi \times K^2 \times l2 \times P_k^2 \times V_{mount}}}{\mathbf{P}_{test}}, \text{ where:}$$

$\pi$ – 3,14,
Q – productivity of water pump,
K – coefficient of friction between the rubber and concrete,
L – width of the rubber plug,
$P_k$ – contact pressure between the rubber element of a plug and concrete walls of pipe,
$P_{test}$ – the testing pressure of water in a pipe.

During time necessary for moving plug to pass the length of the first pipe and time necessary to keep the pressure, the crew would mount the third pipe, and so on. This is the technical basis of combining pipe laying with pipe testing. In a case when during testing some leaking is found, the water pump should be reversed, and water partially pumped out of pipes, the moving plug should be forced back inside pipes using the rod 13 **(Fig. 3)**. After fixing the leak, mounting and testing processes could be continued.

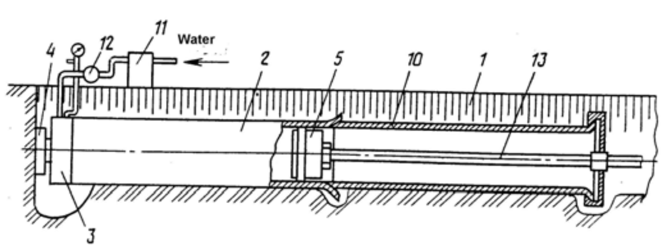

**Fig.3.**
**Public Domain – SU Patent #1,571,156.**
**1 – trench, 2 – first pipe, 3 – end plug, 5 – moving plug,**
**11- water pump, 12 – manometer, 13 - pushing rod.**

Initial ideas of a element-by-element pipe laying and testing seems attractive, but had one principal weakness – the amount of water stored in previously laid and tested pipes would increase dramatically, and as result would overlap any potential advantages. It was a first step of development of a new technology.

The second step was based in minimizing testing part of pipeline within one pipe, and test only each pipe with connection, after it was mounted to pipeline. We can say that this is a contradiction between continuous length of pipeline and limited length of its testing "piece". To solve this contradiction we combined both mounting and testing in equipment for pipe laying crane, and actually, we used the combining principle. The general scheme of developed family of such equipment is illustrated by following picture **(Fig.4).**

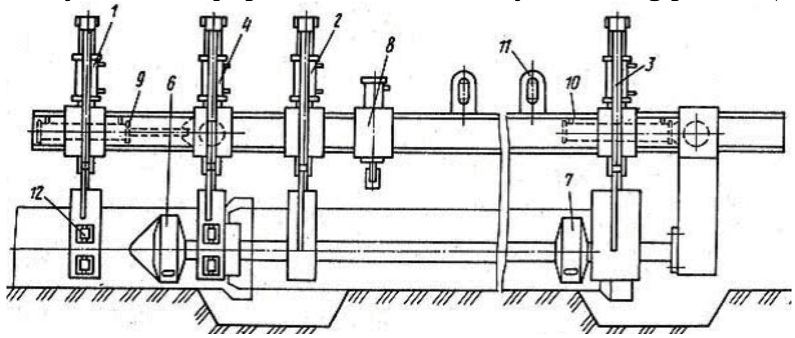

**Fig.4.**
**Public Domain – SU Patent # 1,520,203**
1 – 3 – pipe non-moving holders of pipes, 4 – moving holder of a pipe, 5 –rod for connecting plugs, 6,7 – plugs for testing, 8 – central hangers of device, 9,10 – hydrocylinders, 12 - .

Above shown device for mounting and element-by-element testing pipelines works as follows. During first step holders 1 is open, and device is moved coaxially to a pipe to insert the smooth end of the moving pipe in the funnel-shaped opening of the resting pipe. While the pipelining crane is moving, the rod 5 with plugs 6 and 7 is inserted in a pipe. After the plugs are inserted inside the pipe, holders 2 and 3, and the holders 1 and 4 open the clutches. The pipe in holders 2 and 3 moved down and is centering according the initial pipe. With help of hydrocylinders 9 and holders 4 and 3 the connecting of the pipes, and with help of hydrocylinders 10 the bar with plugs is pushed the pipe, and therefore the plug 6 moved over the connection between pipes. In this way we got inside connecting pipes a testing volume from both sides of pipe connection. By switching on the water pump, we can increase the water pressure to control value, and test the connection. If the result of this testing is positive, we could pump water out, take out the plugs from inside the pipe, move the testing block out of this two pipes work zone. By repeating these operations in the work zone of the next pipes connection, we'll test its quality. We can see the advantage of this version of element-by-element testing – amount of water necessary for testing is minimal, in I a case of test failure, the water could be pumped out easily, and the failed connection could be fixed without loosing significant amount of time. In the **Fig. 5** is shown a photo of such device for testing connections of reinforced concrete pipes with diameter 1200 mm, developed under guidance of authors. In the picture you can see a cylindrical body, from both sides of which there are located rubber plug elements. Under pressure of axial hydrocylinders the rubber rings are compressed, as result they expended axially, and as result they form an empty space the rubber cylinder and internal surface of concrete pipe. This empty space, in other words a cylindrical layer is actual volume of testing.

**Fig. 5.**
**Module with rubber plugs for Testing**
**Reinforced concrete pipes diameter 1200 mm.**

Another version of element-by-element testing is shown in Fig. 6. It is another contradiction, and now it is a contradiction between pipe-by-pipe mounting process and continuous testing process. This contradiction was solved by developing a **self-moving** testing module, the scheme of which is shown in the Fig. 6.

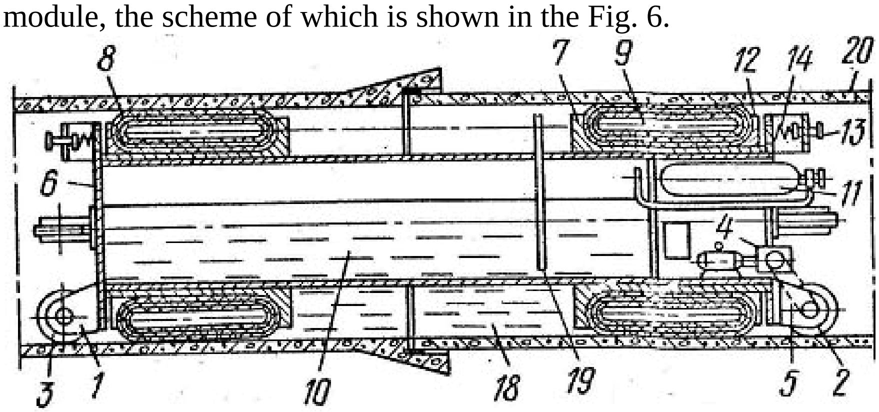


**Fig.6.**
**Public Domain – SU Patent # 1,610,346**
**1- trolley; 2, 3 - rollers; 4 – driving gear; 5 – chain; 6 – frame; 7 – lodgment; 8 – rubber coreless gaskets; 9 – fluid; 10 – capacity with liquid; 11 – balloon with compressed air**

Testing device contains a moving trolley 1 with chassis 2, way rollers 3 and driving gear 4, which are connected by chain 5 with chassis 2. Placed on the trolley 1 frame 6 with lodgments 7, contains rubber coreless gaskets 8, which are made from elastic material and filled with a fluid 9. Capacity 10 for supplying liquid is connected with balloon 11 with compressed air, and systems of electro supply and remote control. Testing device also contains spring-loaded pushing rings 12 for rubber coreless gaskets 8. Screws 13 through springs 14 manage the strength of this pushing.

Being attentive, readers could notice that coreless rubber gasket in above example works as **caterpillar**, one part of which is moving while another part is "staying". In our inventing practice we had more examples of caterpillar effect usage for solving contradictions in technical systems, and we would like to share our experience with readers in one of our next articles.

Installing pipes with element-by-element testing technology could be realized as follows. Testing module is inserted in pipe 20. Capacity 10 and space 18 are filled with liquid. Using remote control system, driving gear 4 and balloon 11 with compressed air are switched on. The compressed gas from balloon 11 entered space 18. Pushing rings 12 under pressure of spring 14 provide contact pressure necessary for compress coreless rubber gaskets 8 between the internal surface of the pipe and lodgments. Testing module is moving inside and lengthwise the pipe. Due to the high friction between internal concrete surface of pipeline and rubber gaskets 8, gaskets are slipping along the lodgments 7, and as result they are not sliding, but are rolling over the pipe. Due to the springs 14, very effective compression of gaskets is provided during all time of operating of the equipment. Possible loosing of a liquid from testing space 18 due to the leaks in pipe joints are compensated by displacement of a liquid from capacity 10 by compressed gas from balloon 11.

Now let's apply (once more in this article!) another one of 40 Inventive Principles, and exactly principle of **combining** (**assembling**). Imagine an **ideal technology** of laying pipelines: pipes are assembled in a line to form a pipeline on the surface of the trench, and then a **magic** - assembled section lowers on the bottom of the trench by **itself**. We hope that everybody could imagine assembled pipe over and along a trench. Such "ideal" technology could eliminate presence of workers on the bottom of the trench in general. Way from "ideal" technology to "real" includes finding resources to realize ideal version in durable technological steps. We developed so-called conveyer technology of pipeline lying, which include two options. First option looks like laying pipelines in tunnels. For this purpose, pipes should be connected one after another, joints between pipes should be tested, and connected pipes should consequently hanged on **monorail system**, and than advanced by monorail in tunnel. After all sections were assembled and advanced, hangers on the monorail were synchronously lowered on the bottom of tunnel. So, ideal result was successfully realized. Interested readers could learn details of this technology in description of patent of former **Soviet Union # 1,767,276**.

In the case of the trench, however, we have additional problem to solve – the stability of the trench, especially with high level of water table in the soil. But specialists already know a standard technological solution for such conditions – filling the trench with bentonite slurry. In this case, assembled part of pipeline could be lowered to the bottom of the trench through bentonite slurry, and will rest on the bottom of the trench. Bentonite slurry than could be pumped out from the trench, and be reused for other processes. Bentonite slurry is used in construction industry mostly to construct cut-off walls in soil. Described technology could expand usage of bentonite products.

Another "ideal" version of a conveyor principle is based on assembling and advancing pipes by the day surface of the trench filled with bentonite slurry **(7)**. In this case, bentonite slurry, having thixotropic properties, will support assembled pipes, keep them in horizontal plane as solid body, and will facilitate advancing the assembled pipes horizontally by pushing. In some cases, to provide necessary floatation of assembled pipes they could be plugged. After assembling all pipes in a section, testing joints between pipes, assembled sections of the pipeline could be lowed on the bottom of the trench by simple pumping out the bentonite slurry. Notice, that in this case thixotropic bentonite slurry has properties of a liquid, and keeps horizontality of its surface while pumping, in this way preventing any inclination **(5)**. This technology is illustrated in **Fig.7.**

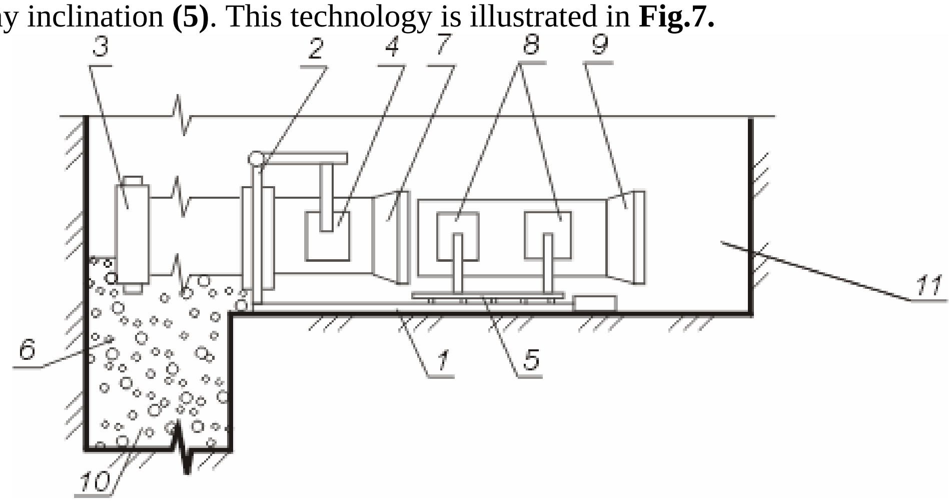


**Fig 7.**
**Public Domain – RU Patent #2,123,630.**
**1 - platform; 2 - protective shield; 3 - plug; 4 - catch devices of the pipes; 5 - moving part of platform 1; 6 - bentonite slurry; 7, 9 - pipes; 8 - catch devices of the pipe; 10 - pipeline trench; 11 - equipment pit.**

As we can see, bentonite slurry provides construction industry with really magic opportunities. We are planning prepare for TRIZ Journal a consolidated article about unique physical and chemical properties of bentonite. We hope that this information will be incorporated in the part of TRIZ, which operates with different effects as powerful inventing tool.

Now let's continue our trip in pipeline technology. We are providing element-by-element testing pipeline, and potentially we can catch its defect. And conclusion is: we have to prepare technologies and materials for their repair. One of the most effective materials to fix defects of pipelines laid using concrete pipes is polymer glue with commercial title "**Sprut**" invented in Kiev (Ukraine) Institute of High-Molecular Compounds **(3).** Mostly technology based on "Sprut" is applied to internal surface of the pipeline. The advantage of "Sprut" glue is its unique property to eliminate water permeability of pipes in presence of water. For example, "Sprut" provide opportunity to fix hulls of the sea ships in underwater conditions. In our practice we have cases, when during hydraulic testing long lines (more than 1000 meters) of reinforced concrete pipes diameter 1200 mm, a lot of pipe connections were leaking. Applying "Sprut" to fix them, we get high appreciation of the construction management. The repair of one connection with "Sprut" glue took about 15 minutes. In the case of rehabilitation of pipelines, when the length of repair is comparable with length of pipeline, we can recommend two technologies. One of them is based on installing liners inside pipeline using Inversion Principle (**2**), which is illustrated in the **Fig. 8.** Device contains a drum with winded on it textile casing, capacity with protective liquid, console for placing membranous hose, tub with glue, empty console for placing the hose, and a bib for placing hermetically the hose in a pipeline. Under air pressure the hose is inverted, and would glue to the internal surface to repairing pipe 4.

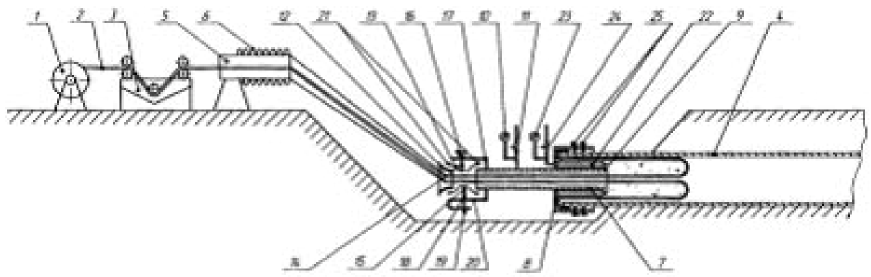

**Fig.8**
**Public Domain – RU Patent # 2,248,497.**

Another option for repairing pipelines using access from inside space of pipes is spraying technology. This technology started using in the USA as cheaper alternative for relining the pipelines. The main problem here is accommodation of right chemical mixtures for spraying. We had experience in chemical protection of gravitational sewerages using polystyrene-cement mixtures. In the table below there are some technical data of **polystyrene-cement** protective coating**.**

**Table 1. Properties of polystyrene-cement coating**

| Property of Coating | Value of property (Uncoated sample) | Value of property (Coated sample) | Method of Testing |
|---|---|---|---|
| Water absorption, % | 0,45 | 1,4 | GOST 12730.3-88 |
| Watertightness | More than B-12 | B-2 | GOST 12730.5-84 |
| Adhesion, kg/sm$^2$ | More than 11.0 | - | CN 389-68 |
| Abradability, g/cm$^2$ | 0,224 | 0,254 | GOST 13087-81 |

Testing of the concrete samples was carried out in the deep well of sewerage collector, in which concentration of hydrogen sulphide was high and variable. We'll note that problem of testing of lining elements inside pipe is very complicated problem. Scientific Center of Trenchless Technologies in Louisiana Tech University constructed special testing complex for such purpose.

**Fig. 9.a**
**General Look of the Spraying Device Inside a Pipe**

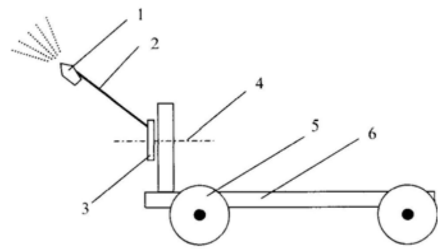


**Fig.9.b**
**General scheme of spraying device**
**1-jet sprayer; 2-carrier; 3-ball-bearing; 4-axle; 5 – wheels; 6 – chassis.**

For spraying polystyrene-cement protective coating on internal surface of concrete pipes special equipment was developed and manufactured. The general look of this equipment inside pipe is shown in **Fig.9**.a and its general scheme in **Fig. 9.b**. Device is placed on chassis, which contains frame and with “jet” sprayer. We developed a special type of a “jet” sprayer, which was **self-rotating**, as it “required” by TRIZ **self-service** principle. During movement of the chassis, the “jet” sprayer is rotating, providing by its rotation stripe-like spraying of polystyrene-cement coating on internal surface of concrete pipes. The scheme of self-rotating “jet”-sparer is shown in the **Fig.10**.

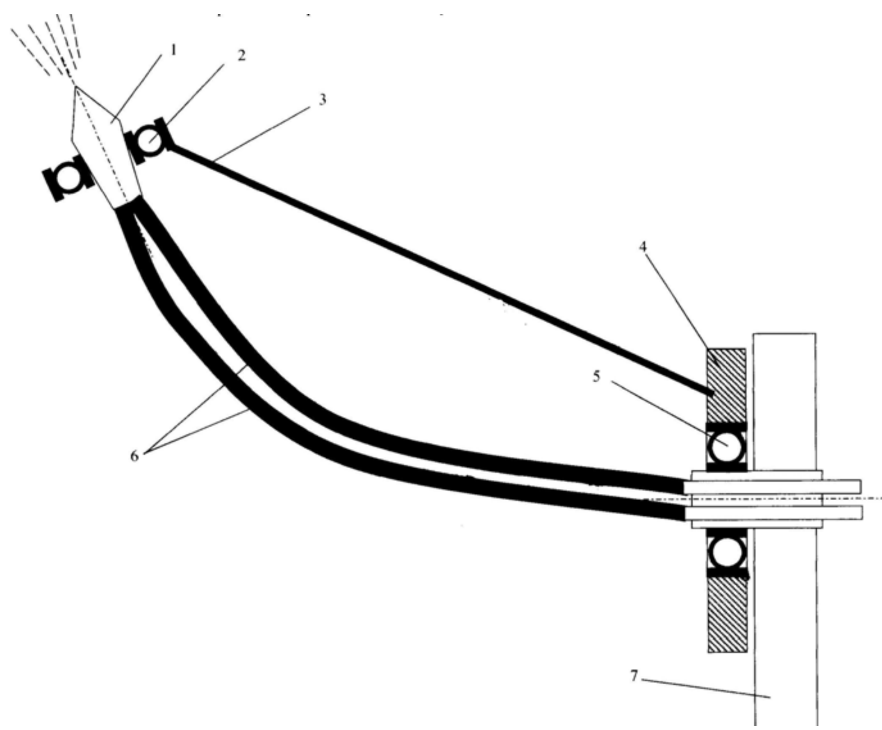


**Fig.10.**
**Scheme of “Jet” Spryer**
**1 – “Jet” Sprayer, 2 – ball Bearing of the “Jet” Sprayer, 3 - carrier, 4 – disk, 5 – ball bearing of the disk, 6 – flexible hoses, 7 – support.**

The “jet” sprayer 1 is connected to carrier through ball bearing 2 with ability to rotate relatively its longitude axle. Flexible hoses 6 are connected from one side to “jet” sprayer 1 and from the other side to sockets, which are placed through hollow axle of the ball bearing 5, which is strengthening to chassis 7. Carrier 3 is strengthening to disk 4 in a manner that during disk rotation the carrier 3 never intersects with flexible hoses 6. If the “jet” sprayer would be connected to carrier, during rotation of the disk with carrier, in flexible hoses 6 would appear torsion strains, which would curtail the hoses in a corkscrew figure. Due to ability to rotate according its longitudinal axle, under appearance of the torsion strains in flexible hoses, the “jet” sprayer is only rotating, taking off the stresses. Spraying device has no moveable gaskets; therefore its reliability is high. The trajectory of spaying by above-described “jet” sprayer is shown in the **Fig.11**.

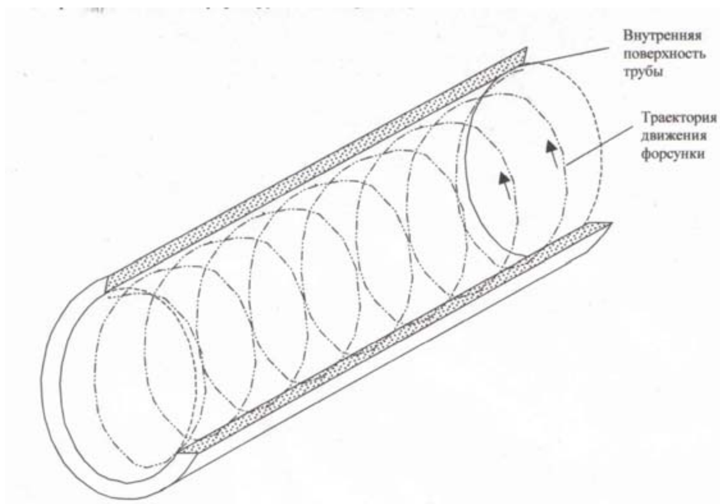


**Fig.11.**
**Trajectory of spaying polystyrene-cement coating**
**on internal surface of the concrete pipe.**

Described equipment (from TRIZ point of view), presents realization of several Altshuller’s Inventive Tricks. First of all, it used here the most economically effective trick – **self-service**. Notice that in described “jet sprayer” as source of energy for rotating is used the potential energy of **twisted rubber tube,** which is at hand here.

Example of one more Inventive Trick we will describe here in the end of article, because it is related with one more method of pipeline defects repairing. This method is based on **memory effect** in polymers, and is disclosed in **SU Patent #1,767,276 (5)**. According to this invention, a strip of a polyethylene is tightly wound on the pipeline, and free end of this strip mechanically or thermally attached to the pipeline. Then over this first layer, wind another strip made from modified by radiation thermosetting polyethylene strip. Then this two-strip system is heated at a temperature 100-105$^{o}$C during 30-40 seconds. As result of heating, the internal strip made from usual polyethylene, is sweating, becoming soft, and under pressure filled the defect place as well as other irregularities around the defect. The second layer of the film doesn’t sweat, and due to the **memory shape effect** in radiation-modified film, it presses out the defect zone of the pipe. The thickness of the first layer of the film has to be bigger than the maximum size of the caverns on 3 –4 mm. The thickness of the second layer of the film should be between 3-9 mm.

We hope that disclosed materials would be helpful for readers interested in TRIZ, and they could use technological ideas and examples in their practice. More information readers could find in referenced literature.

**References:**

1. **Abram Teplitskiy, Roustem Kourmaev, "Application of 40 Invention Tricks in Construction", TRIZ Journal, May 2005.**
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3. **Abram Teplitskiy, "Complex Mechanization of Pipeline Lying," Kiev, Publishing House "Budivelnik", Kiev, 1989 (In Russian).**
4. **Device for pipeline Rehabitation, Russian Federation Patent # 2248497**, **03.20.05.**
5. **Abram Teplitskiy et.al, "Method of repairing a pipeline", SU Patent #1,767,276 Published June 8, 1990.**