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The Construction, Manufacturing and Use of Moineau Pumps in the Romanian Oil Industry

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Abstract

This paper presents the actual status of the construction, making and use of progressive cavity pumps in Romanian oil industry. More companies have been autorized to produce screw pumps: PCM Pompes - France, Mono Pumps LTD – Englandand Robbins Myers Inc. – USA, Nemo Plus-Germany, Le Grand-Canada, Kachele-Germany, UPETROM 1 MAI-Romania, Confind-Campina-Romania. Over the years other small companies which produce these kinds of pumps have switched to the manufacturing of pumps, according to the progressive cavity principle, known today under the name of Moineau's principle.During the movement of the pump a positive displacement, due to the distance between the rotor's axis and the stator's axis,takes place (the eccentricity of the pump).The technological processes have been presented, both for the stator and the stator on the screw pump (spiral), the constructive aspects of screw pumps, the constructive description of helical pumps and instructions for putting into service, the use of helical pumps and the present status of the use of progressive cavity pumps in Romania [1, 2, 8].

Key words*: rotor, stator, rubber, viscosity, eccentricity, oil*

Introduction

At present, porgressive cavity pumps are being built so that they would function in oil wells up to depths of 3000 metres.

Progressive cavity pumps offer the oil industry a great number of advantages as opposed to traditional equipment (beampumping) which often leads to a drop of cost for one ton of extracted oil. Progressive cavity pumps are also called screw pumps or helical pumps.Screw pumps are made of two, three or five worm screws, mounted so that their axes are parallel, and the spirals, being interconnected, form the closing (separating) parts of the asipration and flowing cavities [3].

Screw pumps can be classified into:

- screw pumps with a curved profile;
- screw pumps used in hidrastatic transmissions;
- single rotor screw pumps.

Screw Pumps with a Curved Profile

The conductor rotor is the main shaft which gears two lateral driven shafts. The main turning moment is taken over by the convex profile screw.

In order to seal the flowing chamber and the aspiration chamber, achieving the gearing line is necessary but insufficient.

In order to ensure a sealing it is also necessary for other conditions to be fulfilled. One condition refers to the choosing of the number of concave and convex screws and the number of thread starts.

Screw Pumps Used in Hidrostatic Transmissions

A characteristic of these pumps is, on the one hand, the homogenous flow, free of pulsations, and on the other hand the lack of contorted oil (a process which is characteristic of cogwheel pumps), so that there is no additional interior stress on the radial direction.
In hidraulic systems, the most common pumps are the ones with two or three screws, the ones with five screws being used seldom. [4]

A two screw pump is presented in Figure 1.

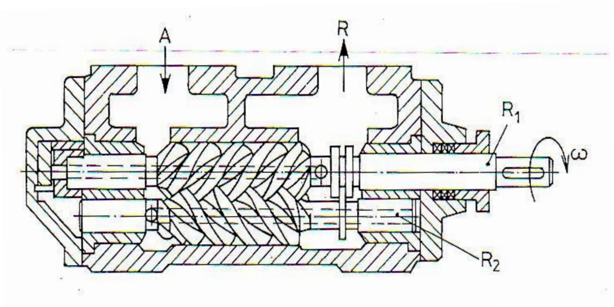

Fig. 1. Two screw pump:
A, R- surface section cross a thread on the portion overlapped;
R_1, R_2- radius of the rotor 1, 2; ω- angular speed.

The two screw pump is made up of a case, inside which the two rotors (screws) rotate, one of which is a driving rotor and the other is driven. The transmission of the movement from the driving screw to the driven screw is being done through direct gearing so that the edges of the spires are in permanent contact and the gearing line ensures a continuous insulation between the aspiration space and the flowing space. For a corect gearing, the profile of the spiral's edges in a normal section of the screws' axis represents an epicycloid curve.

Single Rotor Screw Pumps (Progressive Cavity or Helical Pumps)

Single screw pumps with a rubber stator are used for pumping particle fluids into the suspension (oil, coal dust, juice, sea water, tamato sauce, etc.).

The main advantage in the working of these pumps lies in the fact that a solid particle, caught between the rotor and the stator is spun due to the elasticity of the rubber, thus minimizing the wearing out. This pump is somewhat similar to the sprocket pump with inside drive.

The closing parts belong to the cogged crown (which has two spurs), and the rotor has a single spur (it is a screw with only one start). Screw pumps asre also called progressive cavity pumps.
For this type of pumps, the pumping is done through the volume variation which is deployed during a complete rotation of the pump's working parts. The progressive cavity pump has been patented in 1932 by the engineer Moineau and is also known as: the Moyno or Moineau pump, the screw pump or the helical rubber stator pump [5].

Just as its name indicates, the screw (helicoid or progressive cavity) pump is made up of a metalic rotor in the shape of a screw, with a single beginning, placed eccentrically in the interior of a rubber stator in the shape of a screw with two beginnings and constitutes an interior cylindrical gearing.The functional principle briefly stated is as follows: while the rotor spins inside the stator, between them cavities are formed which "progress" from the the aspiration end to the flowing end, transporting the fluid, volume by volume, throught the pump.In order to achieve the oil pumping, the system must not allow the reverse flow from the flowing chamber to the aspiration one, and the projection of the gearing line corresponding to the total length of the screw has to represent a closed curve. The tight sealing between the propellers of the rotor and the stator keeps the fluid within the cavities formed and due to the spinning of the interior screw. The fluid is driven with a flow that is proportional to the spinning of the rotor. In reality there are leaks due to several factors such as: the difference of pressure between two levels, the wearing out of the rotor and the stator, the solid particles which interpose between the rotor and the stator and which cannot be pushed in the mass of the elastometer in order to achieve the sealing. The diminishing of the leaks can be achieved through an increase in the number of levels, the squeeze between the rotor and the stator, the viscosity of the fluid and the temperature at the level of the pump. This is explained through the fact that the spinning movement of the rotoris a continuous movement, at a steady speed and that is why the liquid comprised in the space between the screws' spires and the pump's shell moves forward at the same speed and, unlike the pumps with alternate movement, the delivery takes place continuously, basically without noticeable variations.

The Rotor of the Helical Pump

The rotor of the helical pump is build out of the material (41 MoCr11) with the symbol 38KHM according to STAS 8185–1988.

As a technological process the following stages are being followed: chipping, marking,eboslathing,control, ultrasonic control,marking the mark and the samples, the treatment of improvement,exterior lathing, ultrasonic control, lathing to brushup, exterior rectifying in order to obtain the linearity and the tolerance in two 0,02mm, shaping helical canals with 0,5mm to finalize, control, lathing the end that served as addition to the machine, shaping the edges, shaping the bush, lathing the rest of the benchmarks completely, control, the stress relieving thermal treatment, adjustment, polishing the edges with a brush and abrasive paste, rough croming, dehydrogenating, straightening after the processing operation and thermic treatments, storing.

Note: As an improvement brought to the making of the rotor, it has been built out of a single piece.

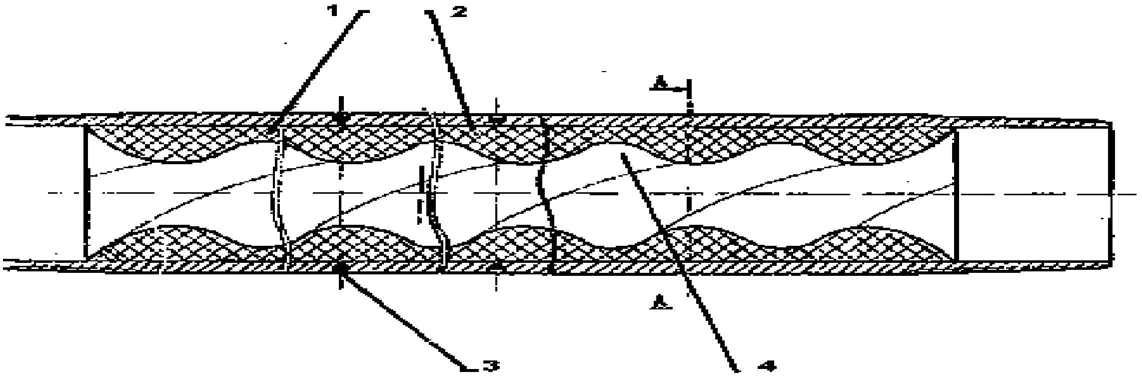

Fig. 2. A section through the rotor-stator assembly:
1 – exterior stator body; 2 – rubber stator; 3 – threaded bolt; 4-rotor.

The Stator of the Helical Pump

The stator is built out of the material (33 MoCr11) with the symbol 35 KHM according to STAS 8185–1988.

As a technological process the following stages are being followed: molding-injecting the rubberthe poured rubber will have the markings and profile according to the image; no lacks in matter and pouring flaws are admitted), exterior lathing, control, rectifying and polishing the sides, rectifying the rubber from the ends of the segment,control,threading the canals - assembling a segment set on the device's axis, tightening - including mounting the device on the machine,alignment, marking the order of the segments in the device,checking the stator on the machine, adjusting the redundancies, marking, storing [7].

Note: An improvement being brought to the making of the stator is to build the stator out of six assembled pieces.

The stator is vulcanized on the interior with an elastomer (rubber) resistant to oil products.

The composition of the rubber is: 6 % -zinc oxide; 4 % -antioxidants; 1,5 % - stearine; 65 % - blacking; 15 % - plastifiant; 0,5 % - sulf, and 4 % - accelerators [12].

The rubber is injected at the interior of the stator through the method of the *horizontal injection* in the vulcanization workshops. Several consecutive resistances are mounted on the exterior of the stator, connected to a 380V power source, so that the heat is transmitted necessary for melting the rubber which is injected through one end of the stator at a constant pressure of 110-115 bar. The electrical resistances on the stator are detached and then the rotoric core will be pulled out from the interior of the stator, and the vulcanised stator will have the rubber from itssection's ends rectified.Then it is stored in order to assemble the rotor itself [9].

Constructive Aspects

The helical pump with a single rotor is also called a single screw helical pump. It is made up of a rotor with a helical profile (a screw) with a single beginning, having a tilt angle of its sipre of 57º-60º. The rotor is placed eccentrically inside a stator which also has a helical profile and which has two opposed beginnings.This way the stator's pitch is double the size of the rotor propeller's pitch. The rotor is made of steel and the stator is vulcanised on the interior. Due to the eccentric position of the rotor towards the stator's axis, while spinning, the rotor will roll over the surface of the stator, and the rotor's spireswill determine closed quantities that move along the axis. Each rotor-stator set is put to the test on the supplier's test stand, such as the German firm KACHELE, a firm which is an expert in elastometers used for the most diverse applications, the most important world producer of rotor-stator sets for helical pumps with eccentric screws.

Moreover, each pumping group belonging to S.C.CONFIND S.R.L. - Campina from our country (Romania), is tested on the firm's own stand in order to certify the achievement of the parameters required by the users.The elastometer (rubber) of the screw pump observes the working conditions of the pump: the driven fluid, its temperature, the solid particle content.In order to resist the agressiveness of salt water and other chemical components, the rotating parts which come in contact with this environment are made of stainless steel or are plated in chrome.The spinning required by the pump is ensured through a transmission with narrow trapezoidal driving belts with inside, Gates-type,dentings. This system is made up of two plates articulated on two rolls and four screws for dumping and blocking the engine plate. The engine support, the main axis module, the aspiration chamber, the actual screw pump and the flowing chamberare fixed on the pumping group chassis. The fastening of the chassis on to the foundation is made using truss bolts. When fixing them on the foundation one should be careful as not to bend the chassis. The instructions for fixing the truss bolts are general for this kind of system largely used in constructions. After fastening it to the foundation, the screw pump is fixed and the connections to the aspiration chamber and the flowing chamber flanges are made [9].

The Structural Description of the Helical Pumps and Instructions for Operating Them

The stages for turning the screw pumps on are as follows:

- checking the pump's protection within the whole installation;
- checking the structure of the installation;
- checking the fastening of the pumping group and the connections on the aspiration and the flowing end;
- checking the stretching of the belts;
- checking the valves on the aspiration and flowing pipes: they ought to be on, but so should the faucet in front of the manometer;
- checking the connection of the devices to the pumps' command pannel;
- checking the engine's grounding;
- checking the engine's connection to the pumping group, in direct triangle start;
- checking the direction of the engine's spinning: looking from the fender, the spinning direction should be "to the left";
- turning on the pumping group;
- checking the functionality of the group: continuous functioning, without any vibrations or excessive heating of the stator from the screw pump.

The constructive elements of the screw pump are presented in Figure 3.

The connection between the rotor and the pumping pole gasket is made through the rotoric coupling. Most of the rotors end at the upper extremity with a cep-type thread.

It is especially mentioned that the rotoric thread is never made in the coupling version because the wearing out of this thread would determine the whole part to be put out of use, and this part is extremely expensive.Because of this, equipping the rotor with a rotoric coupling is preferred.

The upper statoric coupling connects the pump's body and the extraction pipe column.

The pump interior coupling is a device that is placed beneath the pump body in order to ensure it against the unthreading from the extraction pipe column.

The bolt limitating the rotoric movement is useful during the period when the rotor is fixed at the pump deployment depth.

The Use of Helical Pumps

The factors that influence the operation of a helical pumping system are of two cathegories:
A) factors exterior to the internal construction of the helical pump.
B) factors interior to the construction of the helical pump.

In what follows we will analyze each particular factor and the elements through which they influence the functioning and especially the reliability of the helical pump [10].

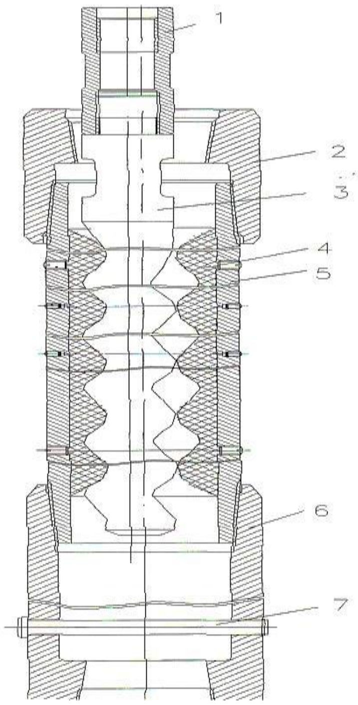

Fig. 3. The constructive description of the helical pump:
1 - the rotoric coupling; 2 - the upper statoric coupling; 3 - the rotor; 4, 5 - the flexible reinforcement and the steel reinforcement which, together, form the statoric assembly; 6 - the pump interior coupling connecting the pump's body and the antispinning anchor; 7 - the bolt limitating the rotoric movement.

A) Factors outside the helical pump

A.I. Geological factors

A.I.a) *The static and dynamic level of the oil from the well which is in use*.

It is known that the static level of a well represents the oil level in the well in static exploitation conditions (when the well does not drill). In periods of production the static level grows up to the value of the dynamic level, a level which stabilizes itself after a certain period of time, when the flow from the layer balances the extraction flow and, implicitly, the production of the well.Once the pump of the helical installation is turned on, it starts to extract the oil quantities accumulated during the static period.On reaching the dynamic level, the following situations may occur:

a1) The dynamic level stabilizes above the placement level of the pump. Usually, it is a good thing for this level to be somewhere around minimum 30 metres above the pump. In case this level drops below 30 metres there is a danger that the level fluctuations in the well would leave the pump without "input", which would determine the possibility of it being damaged in time.a2).The dynamic level stabilizes beneath the pump's placement level - the pump may be damaged after a few hours of use.

a2) There is also a possibility, seldom encountered, in which, following the ecometric measurments, a certain dynamic level would result, above the placement level, but the pump would be damaged according to the second point or it would not produce anything. In these cases there is a "presupposition" that the measured level belongs to a solution under the form of foam which exists up to a certain height, and the pump cannot function within the length of this oil foam [13].

A.I.b) *The sand percentage in the well*.

The sand percentage which results inevitably from the extraction of the oil from the oilfield determine longer or shorter periods when the helical pump is worn out, even if they are constructed especially to work in sandy environments.It should be noted that the couple made up of the rotor (steel) and stator (rubber) is much more resistant to the friction of the sand then the couple made up of the piston (steel) and hull (steel). This phenomenon is explained through the following fact: upon the movement of the sand particle, at first the rubber wall of the stator (due to its flexible nature) engulfs this particle in its mass, so that immediately after (during the flow) it releases it.This way the scratches made on the two hard surfaces of the steel piston and hull are significantly diminished in the case of the steel-rubber couple.At present, the construction of the pumps through networks of making the flexible reinforcement of the stator and through the electrochemical covering of the rotor (i.e. the 65 HRC hard case), offers the pumps a functioning waranty of aproximately 400 days non stop. However, in case the sand percentage in the well is larger than 0.5%, the pumps' reliability is diminished. In the wells where there are large percentages of sand the Grovel-Packing packings are recommended as they help diminish the sand percentage greatly [6].

A.II. Constructive factors of the well

A.II.a) *The tearing of the extraction pipe column during the drilling*.

The means of handling the pump's rotor through the spinning of the pumping gasket, combined with the geometrical shapeof the well determines the fact that, in certain places, due to the pressure of the Earth's gravitational force and/or the influence of the pole's flexibility while being torsioned, bent or stretched, there is considerable friction inside the pole and the extraction pipe column. Under these circumstances, the respective places are strongly submitted to the wearing out which determine the breaking of the tubing and this way putting all the system out of use.

A.II.b) *The tearing of the pumping pole's coupling.*

The tearing of the poles may occur in the following situations:

- the jaming of the rotor in the pin that limitates the pump's movement;
- the formation of a sand bridge which formes inside the stator;
- the breaking of the rubber's adherence and the changing of the stator's geometrical parameters;
- the high wearing out of the poles.

The jaming of the rotor in the limitating pin is an extreme situation but it may occur.

The remedy lies in the corelation through design of the rotor's geometrical shape with the pin's diameter.

The formation of the "sand bridge" takes place when, from unknown reasons, the installation is turned off and the rotor is extracted for a period of time outside the stator. During this period, the sand which exists in the oil column above the pump starts to decant and it deposits itself inside the stator. Upon its reinsertion, the rotor gets jammed in the stator and thus the breaking of the ploes is imminent.The ceasing of the rubber's adherence determines the changing of the profile in which the rotor gears and allows the breaking of the poles through the existing moment of gearing. In these cases the mending can only be done by replacing the whole stator or by removing the unstuck fragment from inside the stator (it depends on the case).

A.II.c) *The tearing of the reinforcement from the pole's axes*.

The pole's axes are intermediary parts which are lain at the binding between two pumping poles in order to maintain the pole on the cental interior space of the tubing. During the use, the tearing of the plastic reinforcement from the axesmay occur and, due to the gravitational force, they wind up in the space between the rotor and the stator, causing jamming.

A.II.d) *The gases' influence and the agressive influence of the oil and its fractions (H_2S) on the stator's rubber.*

Oil represents an agressive environment as far as the rubber reinforcement of the stator is concerned. The manufacturers of helical stators are faced with great difficulties concerning the rubber networks from which the flexible reinforcement is made.

It has to simoultaneously face the following use factors:
1. – the aggressiveness of the environment;
2. – the working temperature;
3. – the sand's abrasive action;
4. – the long periods of use, which means, optimal resistance and flexibility modules.

1. The aggressiveness of the environment manifests on the flexible reinforcement by modifying its physical properties in time.The Shore hardness of the rubberincreases the flexibility module and, at the same time, there occurs a swelling in the rubber which changes the value of the rotor-stator tightness.At first, the increase in tightness does not interfere with the extraction process, but in time, considerable abrasions occur which determine the loss of the pump's tightness. [11]

2. The working temperature is an especially important parameter because if the implications it generates on the stator's rubber reinforcement and the tightness between the stator and the rotor:

a) The stator's rubber reinforcement -we cannot present data due to the fact that all the companies in the world keep this data as manufacturing secrets (NETZSCH, ROBBINS$MEYERS, KAHELE, LE GRAND). What is known is the fact that the temperature splits the use of helical pump stators into two distinct fields.

a.1) pumps that operate at the placement depth at temperatures of below 60ºC
a.2) pumps that operate at the placement depth at temperatures higher than 60ºC

The pumps from the first cathegory are made of NBR type rubber, while the ones from the second cathegory are made from HNBR type rubber.HNBR made stators resist up to temperatures of approximately 110-120ºC and are extremely resistant to wearing out through friction and abrasion [13].

b) The tightness between the rotor and the stator:

The two parts which the stator - rotor couple of the pump are always built with a tightness which varies from case to case (0.3…0.4 mm/radius). However, there are cases when the well's temperature or the oil's viscosity determine conditions which force the use of tightenings of nearly nought.In our country there have been attempts of placing such a pump at the depth of 1800 m at one of the extraction sites in Moreni Prahova, but, due to the complications presented above, the experiment failed, while an attempt is to be made at a later date.This issue seems promising and it is a field in which sustained research will be made so that the helical pumping, which is clearly superior to the old type of pumping, can also be introduced in the case of oilfields with depths greater than 1200-1500 m.

B) Factors inside the helical pump

A helical extraction pump is designed to be used for a period of time.The main advantage the helical pump offers is this period of time, as it reduces consistently the periods for mending the pump, mending which is necessary due to the wearing out by the sand in the well which erodes or blocks the pump hull. The pump being rendered useless is caused by two cathegories of factors:

a) Reasons which relate to the correct assembly of the pump;
b) Factors which relate to the contruction of the elements which make up the pump itself:
  b1) the construction of the stator made from flexible reinforcement;
  b2) the construction of the rotor - it is simple but pretentious.

The Present Status of Progressive Cavity Pumps Use in Romania

Between the years 2000-2012, SC UPETROM SA PLOIESTI has continued the testing of its own equipment, expanding its range of pump tipodimensions in the sense of building 3 ½ in and $2^{7/8}$in progressive cavity pumps in a configuration (1x2). Up to the end of the year 2000, SC UPETROM SA PLOIESTI had used at oil sites around the country approximately 25 pumps, having some of the best results, meaning that the time the pump was used had increased from around 20-30 days to nearly 80-90 days. A very clear example of this is the 1138 Independence well, belonging to the extraction site from Braila, equipped with a Romanian pumping installation (the 3½ in pump) which has functioned non stop for 250 days, as compared to the piston pump which had previously been used in this well and which had a running duration of 20-25 days. At the end of the year 2000, Romania aquired 200 more helical pumps from Robbins& Myers - USA, which were installed in the field. Having considered the characteristics of the handled fluids in the processing of oil in refineries, people use screw/helical pumps when handling high viscosity products at medium temperatures, conditions met in the following cases:

- the fueling of cilindric ovens from the coking installations with liquid fuels (fuel oil);
- the fueling with heavy (viscous) productsat the coking installation in the tank area(at S.C. Petro Brazi S.A., S.C. Petromidia S.A., S.C. Arpechim S.A., S.C. Rafo Onesti S.A.);
- the rubber installations for transporting polymers, with a viscosity that is situated within the cathegory of screw/helical pumps (at S.C. Petro Brazi S.A., S.C. Arpechim S.A., S.C. Rafo Onesti S.A) [5].

Conclusions

Nowadays both in our country and abroad there are attempts at placing helical pumps at depths of over 1500 m and up to 2000 m.The great placement depths of the helical pumps (over 1500m) bring extra complications regarding the manner of pump use.These complications refer especially to problems related to the torsioning of the pumping pole's gasket, considerably large additional friction on the tubing column which lead to the column breaking quickly, problems with fixing the rotor inside the stator which is done in a totally inaccurate manner at these placement depths and which determine a faulty working of the pump and the possibility of a rapid tearing of the rotor through its friction against the walls of the tubing column. Having considered the characteristics of the transported fluids, within the processing of the oil in refineries, they use screw/helical pumps in the case of transporting products wich have a high degree of viscosity at medium temperatures. Such conditions are met in the following cases: the fueling of cilindric ovens from the coking installations with liquid fuels (fuel oil); the fueling with heavy (viscous)productsat the coking installation in the tank area(at S.C. Petro BraziS.A., S.C. Petromidia S.A., S.C. Arpechim S.A., S.C. RafoOnesti S.A.); the rubber installations for transporting polymers, with a viscosity that is situated within the cathegory of screw/helical pumps (at S.C. Petro Brazi S.A., S.C. Arpechim S.A., S.C. Rafo Onesti S.A).

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Constructia, fabricarea și exploatarea pompelor Moineau în industria petroliera din România

Rezumat

Au fost prezentate trei tipuri de pompe cu surub: cu profil cicloidal, utilizate in transmisiile hidrostatice si cu un singur rotor (cu caviatate progresiva sau elicoidale). La pompa cu surub s-a precizat procesul tehnologic atat la stator cat si la rotor. Alunecarile mici dintre rotor - stator si elasticitatea mare a statorului fac ca particulele solide din fluidul vehiculat sa produca uzuri mult mai mici decat la alte tipuri de pompe, asigurand durabilitati mari.Cu toate acestea, pompele Moyno prezinta un randament volumic mai mare decat celelalte tipuri de pompe.S-aprezentatdeascrierea constructiva a pompelor elicoidale si instructiunile de punere in functiune a acestora.Exploatarea pompelor elicoidale se face in functie de factorii exteriori si interiori ai constructiei interne a pompei elicoidale. SC UPETROM SA PLOIESTI a experimentat pompe cu cavitate progresiva, de productie proprie in Schelele de extractie Dragasani, Baicoi si Moreni.