FERTIGATION AND CHEMIGATION INTO THE AUTOMOTIVE IRRIGATION SYSTEM

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1. INTRODUCTION TO THE AUTOMOTIVE IRRIGATION SYSTEM

The Automotive Aspersion Irrigation system is created in order to diminish the costs of a sprinkler installation, and in order to eliminate the system of main and secondary pipes present in an irrigation area. In order to eliminate these pipes several mechanized systems are created. Those are based on the automatic and mechanised shifting of transmitters.

We can distinguish between two different types of mechanised aspersion systems:

- Shifting of a big sized transmitter (Guns); Depending on the shifting system, we can distinguish between "***Travelling Guns***" (a big sized sprinkler fixed on a flexible hose that shifts with the help of a cable) and ***"Traveller machine"*** **(Track)** (a big irrigation gun connected to a flexible hose winded in a barrow. This barrow is shifted thanks to water pressure, and at the same time winds the hose on which the irrigation gun is connected).

Fig. 1: Traveller machine.

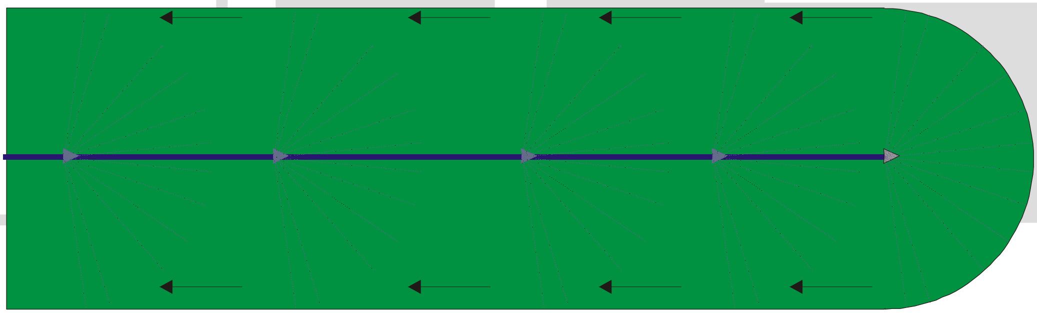


Fig.: Working of traveller machine.

- Shifting of irrigation machine. This kind of equipment achieves a displacement of the whole irrigation machine. All the irrigation area is irrigated by means of a metallic structure – it holds the irrigation pipe and the transmitters – self-propelled and turning around a given point from where it receives water and energy, and also where the control elements are placed.
  There are different types of irrigation machines, distinguished for their kind of shifting. Each of them has a different water transmitter.

Automotive rotary irrigation machine *"Pivot"*; irrigation machine made of a metallic structure that holds the irrigation pipe and the different emitters. This machine is endowed by an automotive system that turns around a fix point.

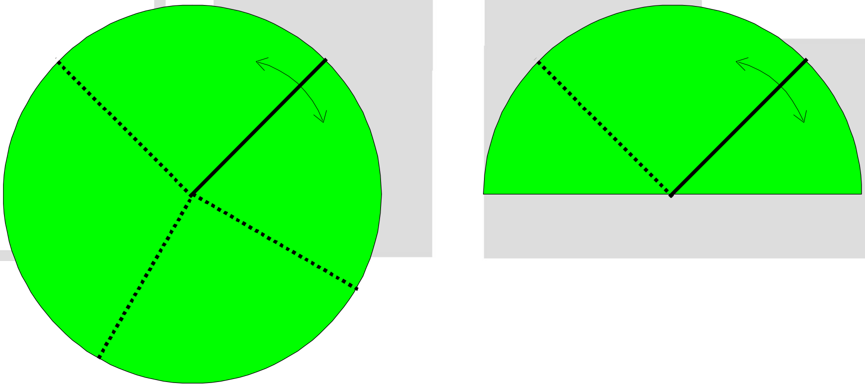


Fig.3; "*PIVOT*" working system

Automotive irrigation machine with parallel movement *"Lateral"*; as above, it is an irrigation machine with its correspondent emitters that shifts perpendicularly to the irrigation pipe.

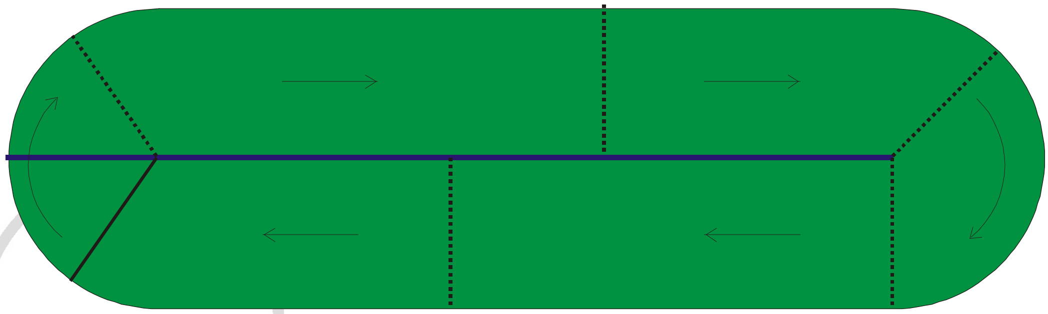


Fig. 4; Shifting of a *"Lateral"*

2.	CHEMIGATION AND FERTIGATION; GENERALITIES FOR AUTOMOTIVE IRRIGATION SYSTEM; PIVOTS AND LATERALS.

2.1 Chemigation

2.1.1 General definition

Chemigation is the application of soluble chemical products in water or in the irrigation line by means of several equipment.
These applications are meant for different targets.

2.1.2 Types of applications

a.) Mechanical; Application of chemical products in order to achieve a general cleaning and maintenance of irrigation equipment and transmitters. I.e.: application of acids for a cleaning of droppers in localised irrigation or of “nozzles” in irrigation by aspersion.

b.) Agricultural; application of chemical products in order to achieve an increase or an improvement in the production of the irrigation area. We can classify them depending on the level of actuation:
Sanitary; application of chemical products such as fungicides, herbicides, nematicidas…
Productive; application of fertilisers in order to stop shortages and to provide the necessary nutritional elements: *Fertigation.*

2.1.3 Factors that affect the application of chemical products;

a.) Properties of the applied chemical product; the properties of the different chemical products must be taken into account depending on the irrigation area, water, soil… Volatility of the different chemical products, their solubility in soil solution, effects of the combination among them…

b.) Solubility; Solubility of chemical products in water determines the moment of application and its viability for fertigation.

- High solubility; Apt for application in fertigation because the possibility of precipitation, obtrusion or breakage of emitters and other equipment is diminished. On the other hand we must take into account that these kinds of products usually are very soluble in soil solution and thus are easily dragged on soil.
- Low solubility; there is possibility of precipitation in the different irrigation equipment provoking the above mentioned problems. On the other hand, their mobility in soil is reduced and thus there are no cleaning problems.

c.) Volatility; It refers to the tendency of different chemical products to pass from liquid to gas condition. This means that losses, in chemigation by pivots or other aspersion systems, increase.

d.) Capacity of absorption by plants; In this case, the capacity of absorption of the different chemical products that we can use on plants may or may not interest us for irrigation purposes. If we apply a chemical product that may be harmful for the irrigation area, we will be interested in a product with a low capacity of being absorbed by plants. On the other hand, when illness corrector chemical products are used, they must be well absorbed by plants – by the root or by the foliage. In this case, we will be interested in a different capacity of absorption. In some cases other components may be used in order to improve this capacity.

e.) Mobility in soil; It is interesting to know this parameter in order to determine the depth on which the main part of the different chemical products will be concentrated, in order to determine the viability of the use of each product.

CHEMIGATION			
Type of Product	Activity	Important aspects	Name
Insecticides – foliage application	Plagues control	Easily absorbed by foliage	Insectigation
Nematicides – soil application	Plagues control	Soluble in water	Nematigation
Acaricides	Plagues control	Most of them with an insecticide effect	Insectigation
Bactericide	Illnesses control	Most of them with a fungicide effect	Chemigation
Fungicides	Illnesses control	Divided in: fungicide applied in foliage and applied in soil	Chemigation
Herbicides	Weeds control	Soluble in water, very volatile	Herbigation

2.2 Fertigation

2.2.1 General definition

Application of nutritive elements in a grow using the irrigation system as a means of transport and localisation in the irrigation area.

2.2.2 General aspects

As explained above, the application of nutritive elements must be done in a given area in order to favour the absorption by the plant, and in order to increase the yielding of the applied fertilisers. Thus, depending on the type of irrigation system, we must take into account the mobility of the different fertilisers in soil.

On the other hand we must take into account that the fertilisers, as chemical products, may arouse problems of chemical resistance, precipitation, volatilisation…

N= Do not mix X= Mix in the injection point.	Ammonium Nitrate	Ammonium Sulfate	Nitrogenated solution	Urea	Calcium Nitrate	Potassium Nitrate	Ammonium Phosphate Monoamonic	Ammonium Phosphate Monoamonic	Phosphoric Acid	Potassium Sulphate	Potassium Chlorate
Ammonium Nitrate		C	X	X	N	X	X	X	X	C	C
Ammonium Sulphate	C		X	X	N	C	N	N	N	C	C
Nitrogenated solution	X	X		X	X	X	X	X	X	C	C
Urea	X	X	X		X	X	X	X	X	C	C
Calcium Nitrate	N	N	X	X		X	N	N	N	N	C
Potassium Nitrate	X	C	X	X	X		C	C	C	C	C
Ammonium Phosphate Monoamonic	X	N	X	X	N	C		C	C	C	C
Ammonium Phosphate Monoamonic	X	N	X	X	N	C	C		C	C	C
Phosphoric Acid	X	N	X	X	N	C	C	C		C	C
Potassium Sulphate	C	C	C	C	N	C	C	C	C		C
Potassium Chlorate	C	C	C	C	C	C	C	C	C	C	

Most of these fertilisers have important corrosive effects. Thus we should carefully choose the material of construction of the different irrigation equipment:

Filters
Emitters
Injection Systems
Pipes
…

Materials such as aluminium, stainless steel, or cast iron are not very responsive to corrosion. On the contrary, brass or bronze are quickly damaged.

Therefore, we must take into account the building materials of all these parts that are in contact with concentrated or solved fertilisers.

FERTIGATION; Nutritional Products			
Type of Product	Activity	Important aspects	Name
Bio nutrients	Activation of growing and developing of plants.	Rich in aminoacids and low proportion of fertilisers	Fertigation
“Emends”	Action on physic, chemical and biological characteristics of soil and irrigation water	Specific correctors (pH, Ec, stabilizers, absorbents…)	Fertigation
Fertilisers	Products that give plants the necessary nutritive elements for their proper development	Organic: generally solid and not very soluble. Minerals; among this group we include fertilisers qualified for fertigation and application in foliage.	Fertigation

3. Chemigation and Fertigation in pivots and Laterals

3.1 General definition

Application of different types of fertilisers by means of an irrigation system based on auto propelled rotary shifting machines (Pivots) or parallel ones (Laterals). This kind of chemigation is characterised by some particularities. Many aspects must be taken into account in order to guarantee the best yielding of chemigation and in order to avoid possible problems.

3.2 Main aspects

As explained above the characteristics of this system will determine several aspects of chemigation.
Firstly the irrigation system must be characterised. This kind of irrigation system is based on the emission of little water drops by means of emitters (sprinklers) creating a “rain” that is distributed through all the irrigation area. All these emitters are placed on a big auto propelled metallic structure (between 60 and 800mm length).
Nowadays some improvements are being made on equipment, in order to decrease the energetic costs and in order to increase the uniformity of irrigation distribution.
Energetically, there is a tendency on the disappearance of impact sprinklers. They need big irrigation pressures in order to work properly. New emitters of the “*spray*” type are now introduced. They use a low pressure in order to work properly. However, the number of transmitters increases in this case, in relation to the number of necessary impact sprinklers.
In relation to the improvement of the irrigation water distribution, in order to increase the distribution uniformity, systems that localise the emitters of irrigation at a lesser height are being introduced.
We can distinguish the present-day equipment depending on their position in relation to the irrigation area;

- **MESA** (*Mid-Elevation Spray Application*); Placed at a mid height between the irrigation pipe and soil. In this case, irrigation is made over the irrigation area canopy.

- **LESA** (Low-Elevation Spray Application); In this case the emitters are placed under the irrigation area canopy. In most cases, in order to use this system, and depending on the plants, we will have to plant in a circular manner.

In order to adjust the distribution of water in the different growing phases of plants, flying-hoses are adjustable to different heights. In this way we can adjust to the different phase of plants growth, and we can also use the system in order to apply fertilisers or other chemical products.

3.3 Chemigation in Pivots;

In order to differentiate in this group between chemigation and fertigation we will only take into account the introduction of chemical products in the irrigation area: nematicides, fungicides, herbicides, insecticides…

Once defined the application field, in general terms it is the most widespread irrigation system used in order to do chemigation. The distribution of the product is done over the entire irrigation surface and in not only in a definite area.

a) Advantages

- **Increase of the application uniformity;** The application of these kinds of chemical products in properly designed systems is very uniform. At the same time we can apply them gilding all the phases of irrigation growth.
- **Reduction of application costs;** The number of workers needed in order to control the system is reduced, as well as the necessary equipment and the time devoted to apply it. Thus, the reduction of costs is quite important.
- **Reduction of daily applications;** In properly designed systems and with adequate programming for chemigation we can obtain a reduction in the number of daily applications.
- **Reduction of soil compaction;** As we do not use tractors there is no possibility of soil compacting.
- **Reduction of mechanical damages caused in irrigation area;** The excessive usage of tractors and other equipment inside the irrigation area provoke mechanical damages in it.
- **Reduction of usage of chemical products;** The possibility of locating the products in the necessary areas as well as the possibility of doing the application in those moments of main necessity allows us to reduce the doses of chemical products.
- **Possible usage of foliage penetration.** In some cases this system is essential when applying a treatment (fungicides, contact herbicides…). If we use this kind of chemigation we can use products that favour foliage absorption. The solubility of insecticides, herbicides …. Must be guaranteed, by using emulsifiers, oils…

b) Disadvantages

- **Potential pollution of water**; Chemical products can be dragged to soil level if: - we irrigate after applying the treatment; -we have problems when emptying the tank due to a bad design of the equipment; - there is an excess of applied product in definite points of the equipment (beginning or end) due to a bad dimensioning of irrigation emitters.

- **There is no uniformity in the application;** If we apply the treatments at inconvenient moments (windy days…) If we have a bad dimensioned equipment, we can have problem in the uniformity of the application, losing great quantities of product or treating surrounding areas.
- **Qualified personnel;** We need qualified personnel in order to develop chemigation. Workers must know about dosage calculations, equipment calibrations (injectors, transmitters, security valves…)
- **Additional equipment**; There is the need of using injectors of chemical products, which will guarantee a definite dosage, as well as equipment in order to guarantee the properly mixing of chemical products in water (agitators).
- **Increase in irrigation time**; the application of products such as herbicides or fungicides in an irrigation system implies the increase in the devoted irrigation time, or even the need to irrigate in unnecessary moments.

3.4 Fertigation in Pivots

Firstly, we should define the action field of fertigation. We understand fertigation as the application of nutritional products in irrigation.
Among these nutrients, we find the following categories:

Bio nutrients: These products active the growth or the plant developing by compounds directly usable by these. The most active of bio nutrients are amino acids. All of them: are bio activating, induce resistance, promote defence and have a repelling effect.
"Growth applications": These kinds of applications affect the physical, chemical and biological characteristic of irrigation soil and water.
We find in this group:

- Specific correctors; Products of synthetic origin that regulate pH in irrigation water and soil solution, desalinise, stabilise, damp and engross.
- Mineral "*Growth applications*"; Mineral origin products.
- Organic "*Growth applications*"; Biological origin products of among which we find liquid products such as humic acid, substrates….
- Biological "*Growth applications*"; Devoted to the multiplication of microbial flora in order to improve the decomposition of organic matter and the formation of absorbable forma for plants.

FERTILIZERS: Products that give plants the necessary nutritive elements.

- *Organic fertilisers;* their fertilising capacity is due to their high content of organic matter. Generally they are available solidly, not soluble in water.
- *Mineral fertilisers*; their fertilising power comes from their high content in natural or synthetic mineral matter. Simple mineral

nutrients, complex ones, shortage correctors, slow liberation nutrients, foliage nutrients, fertigation nutrients…

Taking into account the basic considerations about fertigation we must be aware of certain limiting factors when applying fertilisers by means of this irrigation system. There are some advantages and some disadvantages:

3.4.1 Advantages

- ***Moment of application****;* The application of nutrients can be done through all the vegetative period of the plant.
- ***Types of fertilisers****;* The application of fertilisers with a great mobility in soil allows us to regulate perfectly its content in the whole profile of the soil.
- ***Uniformity of application****;* Application uniformity depends on the uniformity of the irrigation system.
- ***Irrigation tasks****;* Most of the irrigation tasks will be eliminated. Principally in the case of mixing applications of chemical products in order to avoid possible precipitation.
- ***Reduction of fertilisers doses****;* The possibility of applying fertilisers through all the vegetative period as well as the soil mobility factor makes us reduce the applied fertilisers doses, provoking a diminish in the risk of contamination of soil and underground waters if we do a correct timing of fertigation and irrigation.
- ***Reduction of mechanical damages in irrigation area****;* The decrease of irrigation tasks done with tractors reduces the mechanical damages in the irrigation area.
- ***Possibility of applying fertigation in foliage****;* The aerial application of fertilisers over the grow canopy makes possible the usage of foliage fertilisers.

3.4.2 Disadvantages;

- ***Uniformity of application****;* Uniformity in the distribution of fertilisers in the irrigation area depends directly on the good design of the irrigation machine.
- ***Types of fertilisers****;* The mobility of the different fertilisers in the soil limits the type of fertiliser to use. In this way, mineral nutrients rich in potassium, with a low mobility in soil, may not arrive to the root area of plants and thus not be used by them.
- ***Solubility of fertilisers****;* The solubility of fertilisers must be quite high and must not give us precipitation problems. That is why there is an increase in the cost of nutrients because there is no possibility of buying cheap fertilisers such as ammonic anhydride.
- ***Volatility of fertilisers****;* the volatility of some fertilisers must be taken into account, i.e.: fertilisers rich in ammonium.

- ***Corrosivity** of fertilisers;* the possibility that some parts of the system get in contact with fertilising products must be taken into account. Thus we must avoid the use of non-resistant materials.

3.5 Conclusions

The irrigation system for pivots and laterals using **CHEMIGATION**, and in particular for the treatment of illnesses and plagues in irrigation areas, is a widespread system that conveys an improvement in all fields against the traditional methods. We only need a correct timing in order to do the application in the right moments (no wind, low temperatures, no light) and to have into account the volubility and solubility of the applied products .

In relation to **FERTIGATION**, it is advisable the use of only those mineral nutrients with a high mobility in soil in order to ensure their proper yielding, as well as all those with also a high solubility. That is why nowadays fertigation with Pivots is devoted almost exclusively to the application of nutrients with an important quantity of nitrogen. As explained above, we should do a good calibration and design of the system as well as a proper temporisation in order to guarantee its maximum yielding.

4. Chemigation and Fertigation Equipment

4.1 Possible injection equipment

Having into account the need of this kind of irrigation system and the particular needs when applying chemical products or nutrients, we distinguish between two kinds of injection equipment

Passive injection equipment; the usage of this equipment conveys a decrease in the irrigation line pressure, or a loss of water flow. In addition, the calibration and adjustment of their injection flow is quite difficult. Nowadays the usage of these equipment is diminishing, for systems conveyed to work with reduced pressures are being designed. Moreover, the possibilities of automate these injection systems are much reduced and are based on the use of solenoid valves and pulse meters. In some cases, in particular in small irrigation systems we can use proportional hydraulic injectors. That allows the incorporation of one or two injection modules in order to dose one or two different products.

Active injection equipment; All the active injection systems used for agricultural purposes have electric motors that allow a very reliable control of the injection by using inverters, servomotors, etc.

Among these systems, nowadays the most used are:

Piston pumps; This equipment allows choosing the kind of nominal injection flow of the pump, and at the same time securely adjusting the injection percentage. In addition, there is the possibility of attaching to a pump several injection modules in order to apply more than one product at the same time.

Diaphragm pumps; This kind of injection pumps are designed for the injection of reduced flows. In general and for agricultural purposes their use is recommended for chemigation in low flow and low pressures systems.

4.2 Calibration of injection equipment

As explained above, in order to guarantee a proper application of products it is important to do a good dimensioning of the injection equipment. On one hand, injections inferior than needed mean a low yielding of the application menacing the irrigation area development. Excessive injections mean losses of fertilizers but can also convey the pollution of soil, underground waters and the burning of foliage.
In order to do a proper dimensioning and calibration, we have to take into account the following parameters:

Pivot circumference;

$C = 2\Pi R$

Treatment area;

$A = \Pi R^2$

Travel speed;

Traveled distance in 10 minutes while the system is irrigation the water volume on which we wish to apply the products. (V)

Revolution Time;

Time spent by the system in doing a complete circumference while using the wished volume of irrigation water.

Tr; C/V

Treated area per minute (m^2);

$A_t = A/Tr$

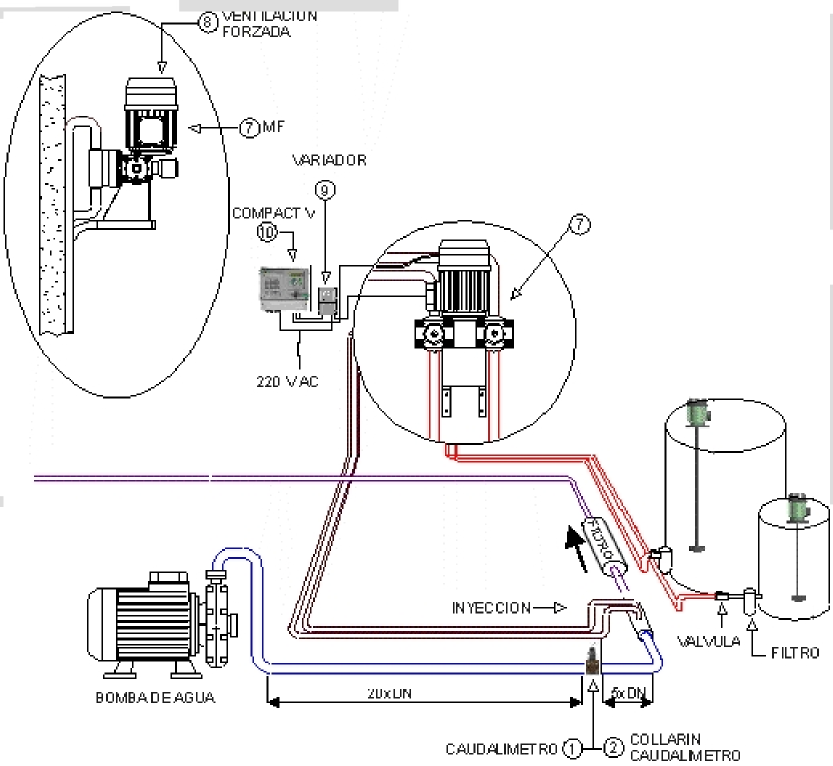
Application flow;

$Q_a = VpxA_t$

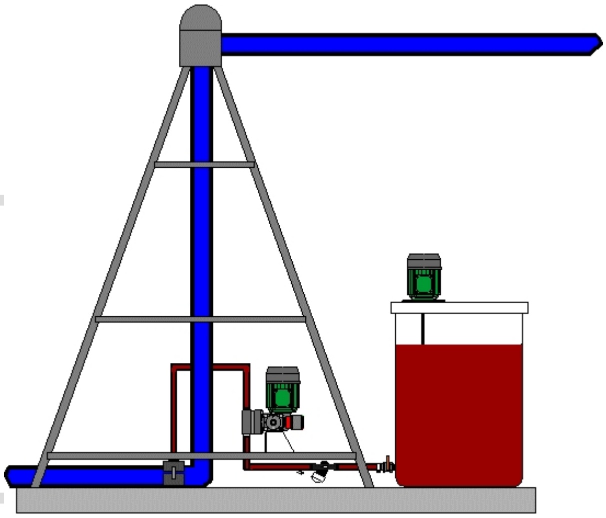
On Vp = Necessary volume of product per m^2.

At = Treated area per minute

4.3 Injection equipment installation



a) **Equipment situation;** Chemical dosage equipment is usually placed inside the “irrigation head” of the irrigation systems, in the case of fixed systems.
In mobile irrigation systems, equipment is placed on the Pivot base.



b) **Equipment installation;** Chemical dosage equipment must have the following elements in order to guarantee their proper operation:

- Tank of chemical products or fertilizers.
- Ball valves of the fertilizer tank.
- Aspiration hose.
- Filter in order to guarantee the absence of solid particles in the fertilizer solution.
- Injection pump.
- Non-return valve: it avoids water coming into the tank and at the same time helps in the mixing of the product injected in the irrigation system.
- Agitation system in the tank.

In both cases dosage is done before getting to the vertical pipe of the pivot, so that the angles can properly mix water with the injected product.

In some cases in order to guarantee a proper dosage we can use injection control systems based on a proportional injection or on achieving pre-established EC or pH values, as well as temporization systems.

4.4 Basic requirements of injection equipment

Injectors of chemical products should have the following requirements;

- Manually and automatically adjustable.
- Manufactured with chemical resistant materials.

- Availability of spare parts.
- Possibility of injecting one or more products simultaneously.
- Capacity of adjusting injection flow up to 5% with grades of 1%.
- Correct dimensioning for minimum and maximum needs.

a) Electric pre-installation Kit; This Kit offers all the necessary elements to install an injection pump with an injection module connected to a tank for chemical products.
   This Kit offers the following elements:
   - General components;
     Modular electric injection pump **MULTIFERTIC®**
   - Hydraulic components
     Ball valve to close the tank
     Filter to aspirate fertilizer
     Hose
     Non-return valve
   - Electric components;
     Electric connection terminals
     Circuit breaker
     Circuit breaker protection box
     Connections cable

b) Pre-installation Kit with support for tanks with fertilizers: This system is aimed for small installations with a tank, an injection pump and an agitator.

   This system offers;
   - General components;
     MULTIFERTIC® modular injection pump.
     Turbine agitator
     Support bar **KIT-PIVOT** to install in fertilizer tanks.

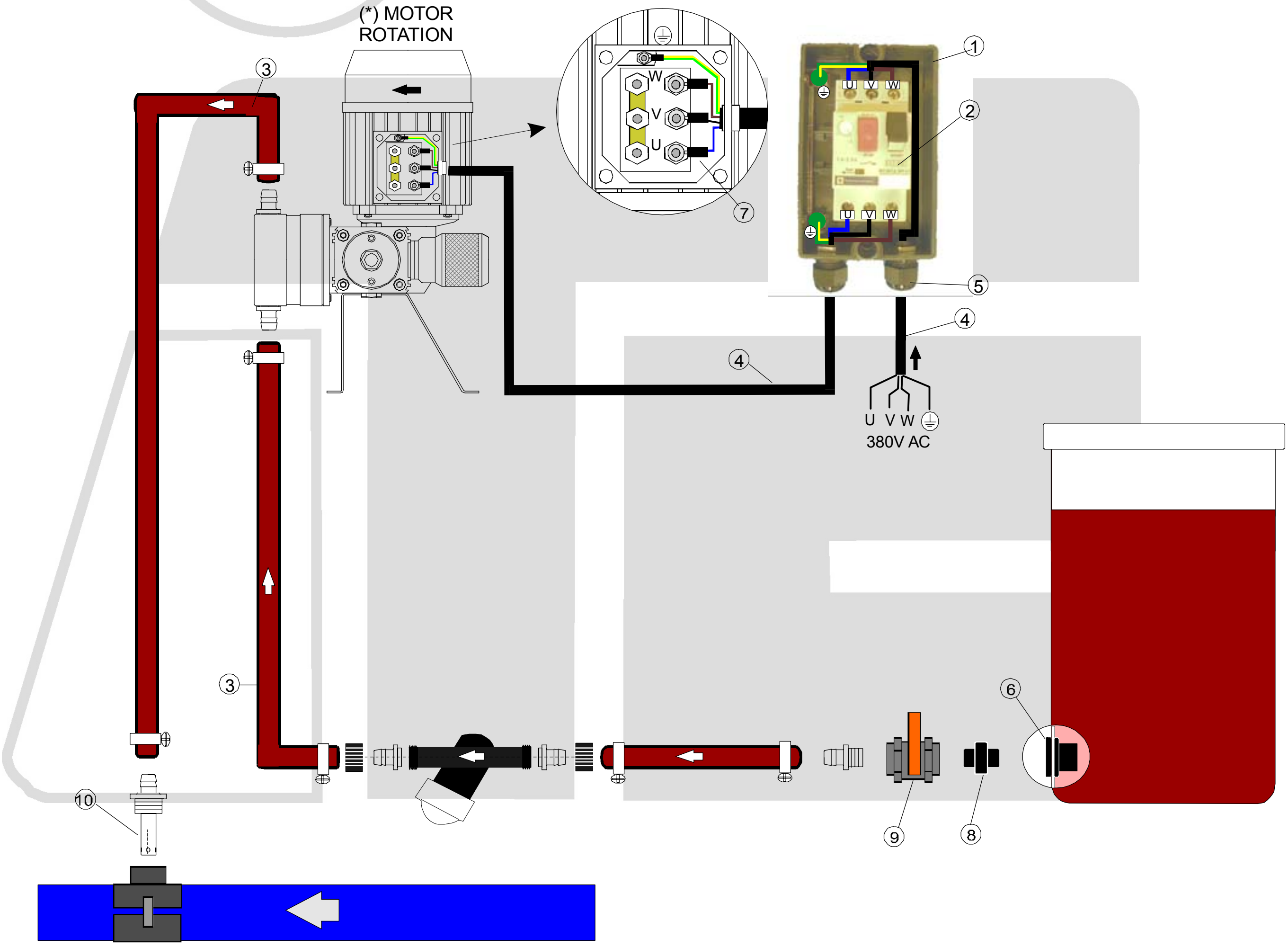
   - Hydraulic Components;
     Filter to aspirate fertilizer
     Hose
     Non-return valve
     90º angle

   - Electric components;
     Electric connections terminals
     Circuit breaker
     Circuit breaker protection box
     Connections cable

Electric pre-installation Kit;

Components:

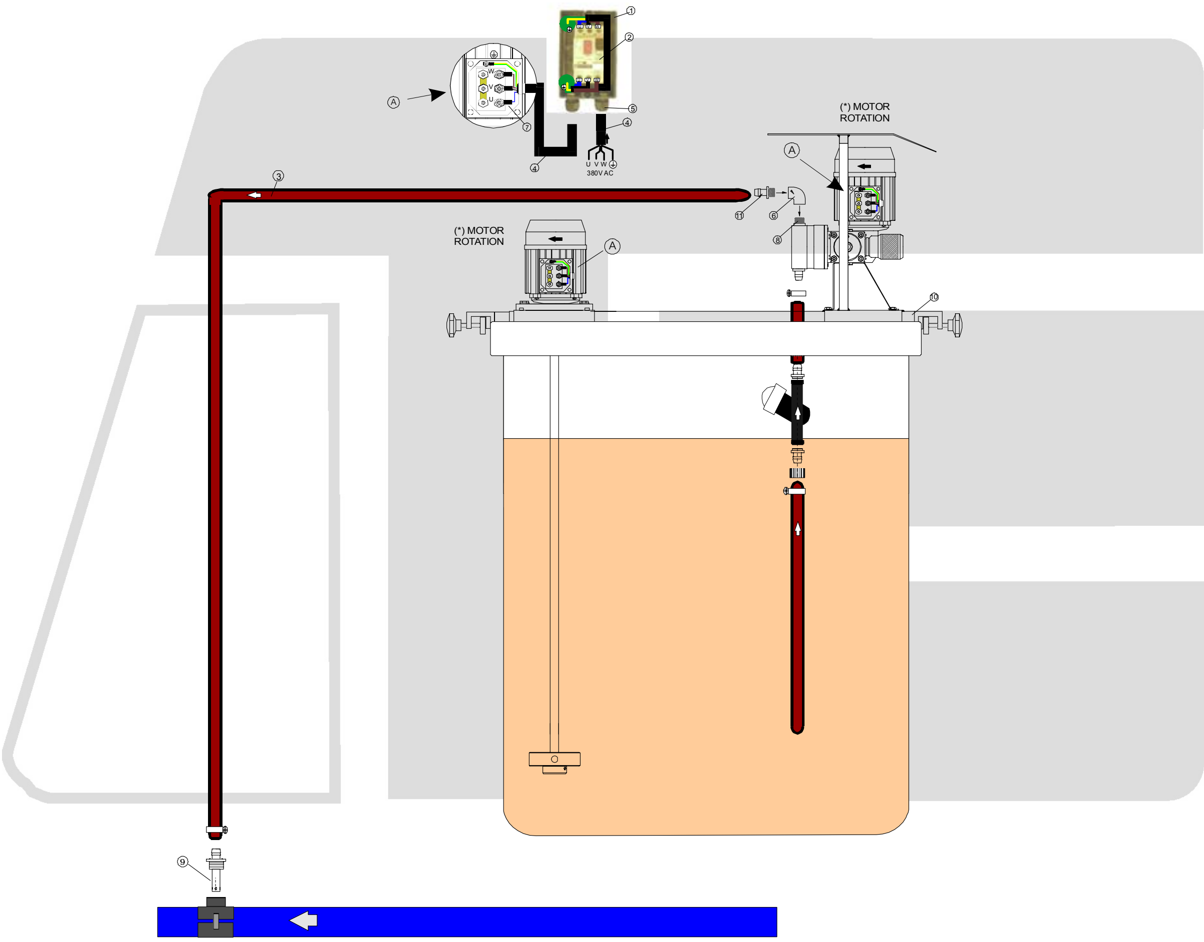
NUMBER	CODE	DESCRIPTION	UNITS
1	20CAJ GMT 0.5	CIRCUIT BREAKER BOX	1
2	20MAG 0.5 TRI	CIRCUIT BREAKER 0.5 CV	1
3	20MNG 15X21 FL	PVC HOSE 15X21	10 m
4	20MNG 4 X 1	CABLE 4 X 1.5	10 m
5	20 PRE PG16	PG 16 GLAND	2
6	20PSM ½	WALL CHISEL ½	1
7	20TER 1.5	TERMINAL CONNECTOR 1.5	4
8	30MAC ½	½ " NIPPLE	1
9	20VAL BOL ½	½ " VALVE	1
10	50VAL ANT DIF	NON RETURN VALVE 3/4"	1



Pre-installation kit with telescopic support for fertilizer tanks:

Components;

NUMBER	CODE	DESCRIPTION	UNITS
1	20CAJ GMT 0.5	CIRCUIT BREAKER BOX	2
2	20MAG 0.5 TRI	CIRCUIT BREAKER 0.5 CV	2
3	20MNG 15X21 FL	PVC HOSE 15X21	10 m
4	20MNG 4 X 1	CABLE 4 X 1.5	20 m
5	20 PRE PG16	PG 16 GLAND	4
6	20COD 1/2H	90ª ELBOW 1/2"	1
7	20TER 1.5	TERMINAL CONNECTOR 1.5	8
8	50VAL IMP 1/2M	IMPULSION RETENTION VALVE 1/2	
9	50VAL ANT DIF	NON RETURN VALVE 3/4“	1
1	60KPV XXX	KIT PIVOT TELESCOPIC SUPPORT	1
11	30RAC IMP	1/2" IMPULSION CONNECTOR	1



5. GAUGING THE CHEMIGATION AND FERTIGATION EQUIPMENT IN PIVOTS AND TRAVELLERS

5.1 Introduction

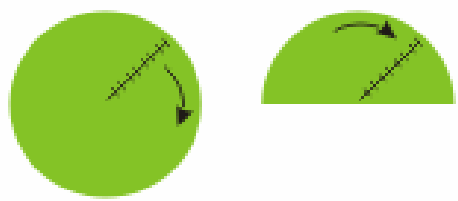
One of the main issues when you have to carry out a chemigation and/or fertigation correctly is to ensure a high uniformity of application. This uniformity will be attained, in the first place, if the irrigation layout (design of Pivot or Lateral) is good, and after that by using an injection equipment of the right size.

In order to correctly establish the size of the injection equipments some aspects of the injection equipment, of the crop, etc. must be kept in mind, be travelers other features of the fertigation and chemigation systems used.

- Area to be treated.
- Amount of product needed to carry out treatment.
- Number and length of treatments.
- Volume of injection.
- Gauging the volume of injection.

5.2 Gauging of a chemigation/fertigation system for central pivots

As in the remaining irrigation systems, we base ourselves on the uniformity of application data obtained, on the irrigation time, irrigation area, etc.



a) **Fixing the area for treatment.** In this case the treated area is a circle and we must keep in mind the use of final guns when the application is carried out.

Area (At in m²) = π x r²

Where: $\pi = 3.1416$
r = length of Pivot,
Plus the actual irrigated distance of the irrigation gun, when used.

b) **To establish the total amount of chemical product needed.** Having in hand the agronomical data, such as the crops needs, number of plants per hectare, etc., we can establish a basic parameter for this process:

Needs (Nq); Kilo per Product per hectare
l. per product per hectare

Chemical Product = AT x Nq

Where: At = treated area in hectares (AT/10000)
Nq = liters per hectare needed. If we have the value in kilos per hectare we shall convert them to liters, keeping in mind the chemical product used and the concentration of the solution prepared.

c) **Treatment time needed**. It is the time needed by the Pivot to make a full circle. This parameter must be measured carefully and correctly. We must calculate the speed of the system with wet ground, and the pressure and the irrigation flow which we will use when carrying out the applications.

This measurement can be carried out in two different ways:

- Measuring the time needed by the Pivot so that the last tower of the Pivot be able to reach a given distance (over 20 m.).
- Measuring the distance covered by the last tower of the Pivot in a given time (10 min.).

The best solution would be to calculate the actual time needed by the Pivot to carry out a full turn.

In the first place we must keep in mind that speed is calculated by means of the last tower, and not the final section of irrigation. Therefore we must establish the total distance covered by this tower:

R = 2 x π x r

Where: r = the distance from the middle point of the Pivot to the last tower, and R is the total distance covered by the last tower of the Pivot.

In the second place we must keep in mind the rotating speed and calculate the revolutions per minute (r.p.m.) of the Pivot.

Rotating speed (Vr in r.p.m.) = R / speed of turn (Meters/minute)

Where: Vr = Pivot's revolutions per minute
R = length of one revolution

d) **Number of applications**
We must establish the number of applications by means of which we must measure out the amount of product to be used as per b).

After deciding the number of applications (Na) per week and month, we shall carry out the following operation to establish the injection flow for each application.

Application amount (Da in l./application) = Chemical P./Na

Where: Chemical P. = the volume of chemical product we need to make the treatment.
Na = the number of applications we will effect to make a full treatment.

e) **Injection flow of the chemigation/fertigation systems**

It makes reference to the total volume of product to be measured out in each application, divided by the rotation speed of the system (r.p.m.).

Injection flow (q.inj. in l./h.) = Da / Vr.

Where: Da = the volume of chemical product we shall use in each application.
Vr = revolutions per hour of Pivot (r.p.m. x 60).

f) **Gauging of the injection flow**

Keeping in mind the injection flow given out by the previous calculations, and the existing models in the market of injection pumps, we can carry out the first gauging of the equipment, to establish the percentage of injection which must be used.

% Regulation = theoretical q. inj. / actual Q x 100

Where: theoretical q.inj = the injection flow calculated under d).
Actual Q.: = the nominal injection flow of the module of injection pump available.
% regulation = the regulation % of the module of the available injection pump.

In most cases we will choose to work with regulation percentages over 75% of the maximum capacity of the pump, since in this way we ensure the possibility of working correctly with larger or smaller flows. Simultaneously, regulations below 10% may produce inconsistent and inaccurate dosing flows.

g) **General information on sizing**

Generally speaking, the sizing of the injection pump for Pivots corresponds to the following equation:
Nominal flow of injection pump

$$\textbf{q. iny.} \geq \frac{3 * Lp * Nn * Vp}{1000 * Sol * Na}$$

Where: Lp: Length of Pivot in meters
Nn: Nutrition needs (kg./ha.)
Vp: Speed of Pivot (meters/min.)
Sol: Solubility of fertilizer (kg./l.)
Na: Number of applications. Fertigation frequency.

Recommendations:

- The solubility value of the fertilizer to be used to prepare the mother solution will be equal or higher than the solubility value suggested by the manufacturer.

- In areas with heavy rainfall, we must keep in mind the possible variations of the application frequency, which might imply changing the sizing of the injection pump.

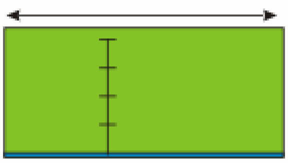
5.3. Gauging of a chemigation/fertigation system for laterals

As for the other irrigation systems, in this case the fertigation and chemigation are based on obtaining information of application uniformity, irrigation time, irrigation area, etc.
In all the cases they work in the same way as the gauging of the middle Pivots. The only feature which changes with respect to fertigation/chemigation in Pivot is the crop area and the calculation of the lateral speeds of the irrigation section.

a) **Fixing the treatment area.** In order to calculate correctly the treatment area we must keep in mind the farming system and calculate it as the sum of different regular areas in case they are not regular.

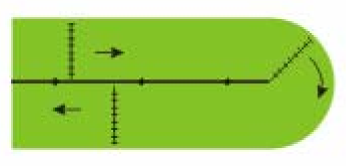
Lateral : the irrigation area is a rectangle:

Area (At in m²) = l x d



Where: l = length of piece of land treated (Channel, piping, etc.)
d = length of Lateral, plus actual irrigated distance of the irrigation gun, if used.

Racetrack system: in this case the treated area is the sum of two areas calculated separately:



Area 1 /At1 in m²) = l x d
Area 2 (At2 in m²) = π x d²

Total area (Total A in m²) = At1 + At2

Where: l = length of piece of land treated (channel, piping, etc.)
d = length of Lateral plus actual distance irrigated by the irrigation gun, if used.
π = 3.1416

b) **Fixing the total amount of chemical product needed.**
Taking into account the agronomic information and the cultivation needs, number of plants per ha, etc., we can establish a basic parameter to fix the amount of chemical product needed.

Needs (Nq): Kg. = product per ha.
L = product per ha.

Chemical product = Total A x Nq

Where: Total A = treated area in hectares (At/10000)
Nq = needs in l./ha. If the value we have is Kg./ha., we shall convert it to liters, taking into account the chemical product used and the concentration of the solution prepared.

c) **Needed treatment time**
It is the time needed by the Lateral to make a full cycle. This parameter will have to be measured in a correct and precise way. We must calculate the speed of the system with wet ground, and the pressure and irrigation flow which will be used during the applications.
Should we have a *Racetrack System*, we shall have to distinguish among the different speeds concerning the rectangular part (of the Lateral) and the turning speeds of the Racetrack where it acts as a Pivot.

Traveling speed of the Lateral. It is a direct measurement as we shall have to calculate the time needed by the Lateral to travel a given distance, or the distance traveled in a given time.

Traveling speed (Vr in m./min.) = l/T (meters/minute)

Where: l = length of terrain treated
T= time the Pivot needs to travel this distance

Revolution speed of the Pivot part. As in the gauging of the chemigation systems by means of Pivots we shall calculate taking into account the last tower of the irrigation section. In the first place we shall determine the distance traveled by the tower, and in the second place we shall take into account the established revolution speed, and we shall calculate the revolution per minut of the pivot (r.p.m.)

Finally we shall take into account the arc traveled by the Pivot, whether it is a full revolution or only a partial one.

$R = 2 \times \pi \times r$ (one full revolution)
$R = \pi \times r$ (one half of a full revolution)
$R = 1/2 \times \pi \times r$ (90º)

Where: r = the distance from the central point of the Pivot to the last tower
R = the total distance traveled by the last tower of the Pivot

Revolution speed (Vr in r.p.m.) = R / Speed of turn (meters/minute)

Where: Vr = revolutions per minute of Pivot
R = Length of one revolution

Finally, after ascertaining the two speeds we can establish the time taken by the system to make a full cycle we shall calculate it as a **total V (in) r.p.m.**

d) **Number of applications**

We shall establish the number of applications needed for dosing the amount of chemical products established account the established revolution speed, and we shall calculate the revolutions per minute of the Pivot (r.p.m.).

After we have decided the number of weekly and monthly applications, we shall have to carry out the following operation to establish the amount of solution to be used for each application.

Application dose (Da for application/l.) = Chemical P./Na.

Where: Chemical P. = the volume of chemical products needed to carry out treatment.
Na = the number of applications which we shall carry out to make the treatment.

e) **Injection flow of the chemigation system**

It refers to the total volume of product to be measured out in each application (Da.), divided by the traveling speed of the system.

Injection flow (q.inj. in l./h.) = DA / V total

Where: Da. = is the volume of chemical product which we use for each application.

V total = is the speed of the Lateral

f) **Gauging of the injection flow**

If we take into account the injection flow established by the previous calculations and the models of injection pumps existing on the market, we can now make a first gauging of the equipment, to establish the injection percentage to be used.

Regulation % = theoretical q. Inj. / actual Q x 100

Where: theoretical q. inj.= the injection flow calculated under d).

Actual Q. = the nominal injection flow of the available model of injection pump.

Regulation % = the percentage of regulation of the module of injection pump available.

g) **General information on sizing**

Generally speaking, the size of the injection pump for Laterals is given out by the following equation:

Nominal flow of injection pump

$$\textbf{q. iny.} \geq \frac{Ll * Nn * Vp}{10000 * Sol * Na}$$

Where: Ll: Lateral length (in meters)

Na: Nutrition needs (kg./ha)

Vp: Speed of the Lateral (meters/min.)

Sol: Solubility of fertilizer (kg./l.)

Na: Number of applications. Frequency of fertilization

5.4 Gauging example of a fertigation system in pivots

Fertigation program for corn irrigated by means of an 80 m long Pivot. The formulation of the fertigation is based on a corn crop, in a given phenological condition. The required nutrition needs, determined by means of a soil and leaves analysis, will be:

25 kg N/ha., Ammonium Nitrate (33.5-0-0)
11 kg P205/ha., Monoammonium Phosphate (MAP, 10.5-52-0)
23 kg K2O/ha. (0-0-30)

a) Crop area and length of Pivot:

At = π x 80² = 20106.20 m² = 2.01 ha.

b) Nutrition needs and amount of product to be applied:

Potash:

$$23 \text{ kg. } K_2O \; \frac{100 \text{ kg. fertilizer}}{30 \text{ kg. } K_2O} = 76.67 \text{ kg. fertilizer}$$

There are 25 kg/sack, wherefore we should use 3 sacks:

$$75 \text{ kg. fertilizer} \; \frac{30 \text{ kg. } K_2O}{100 \text{ kg. fertilizer}} = 22.5 \text{ kg. } K_2O$$

Monoammonium phosphate:

$$11 \text{ kg. } P_2O_5 \; \frac{100 \text{ kg. fertilizer}}{52 \text{ kg. } P_2O_5} = 21.15 \text{ kg fertilizer}$$

There are 25 kg/sacks, wherefore we shall use 1 sack:

$$25 \text{ kg. fertilizer} \; \frac{52 \text{ kg. } P_2O_5}{100 \text{ kg. fertilizer}} = 2.63 \text{ kg. N}$$

Ammonium nitrate:

2.63 kg. N (provided by MAP)

25 kg. - 2.63 kg. N = 22.37 kg. N

$$22.37 \text{ kg. N} \; \frac{100 \text{ kg. fertilizer}}{33.5 \text{ kg. } P_2O_5} = 66.78 \text{ kg. fertilizer}$$

There are 25 kg/sacks, wherefore we shall use 3 sacks:

$$75 \text{ kg. fertilizer} \; \frac{33.5 \text{ kg. N}}{100 \text{ kg. fertilizer}} = 25.13 \text{ kg. N}$$

In this way we shall obtain the following composition, which we shall mix in the fertilizer tank:

Fertilizers supplied in kg.	Nutrients supplied in kg.	Nutrients required in kg.	Difference
75 kg. Ammonium nitrate 25 kg. Monoammonium phosphate	25,13 Kg. + 2,63 Kg. = 27,76 Kg. N	25 Kg. N	+ 2,76 Kg.
25 kg. Monoammonium phosphate	13 Kg. P_2O_5	11 Kg. P_2O_5	+ 2 Kg.
75 kg. Potash fertilizer	22,5 Kg. K_2O	23 Kg K_2O	- 0,5 Kg.
Total kg. (Nq)	**175 Kg / ha**		

Chemical product = At x Nq = 2.01 x 175 kg. = 351.75 kg.
It needs not less than 600 liters water for its solubilization.
We shall use a container of 1000 liters. **Dose: 0.352 kg./l.**

c) Treatment time:

Pivot travel:
R=2 x π x r = 2 x 3.1416 x 80 = 502.65 m.

Treatment time:
We take as average speed of Pivot V revolution = 1.40 m/min.

Treatment time=R/V rev.= 502.65 / 1.40 = 359 min. = 5.98 h.

d) Number of Applications per week / month:

We consider a weekly application wherefore the application dose (on a monthly basis) will have to be divided by the number of weekly applications.

$$\textbf{Application dose Da} = \frac{1000 \text{ l. solution}}{4 \text{ applications}} = \textbf{250 l. solution/application}$$

e) Injection flow of products:

We must carry out an application of 250 liters for each treatment. This solution must take place in a homogeneous way all along the travel of the Pivot.

Q inj.= chemical product/Vr = 250 l. / 5.98 h. = 41.80 l./h.

f) Gauging of injection equipment:

In this case the fertigation equipment will be made up of an injection pump with a module with a nominal flow of 50 l./h. (real Q = 50 l./h.). For this reason the equipment must be regulated as follows:

Regulation % = theoretical q / actual q x 100 = 41.80/50 x 100 = 83.6% ~84%