FERTIGATION
IN GOLF COURSES

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1. General Information on Golf Courses

Grown species

The species grown in the golf courses belong exclusively to the gramineae, and must grow in a continuous and homogeneous ground cover, which in practice implies the ability to suffer a frequent mowing all along its life, and to be able to stand the mechanical wearing out caused by the transit over it of people and vehicles.

The species most frequently used in our golf courses are Festuca, Lolium, Poa, Stenotaphrum, Agrostis and Cynodon.

Continuous cultivation

A requirement of growing the grass in a golf course is that we will not be able to "lift" it for all of its vegetative cycle, which makes it difficult to gain access to the root area to carry out a work that in other crops can be used to fertilize, airing, weeding out and carrying out phytopathological jobs.

On the other hand mowing the grass, even if it is necessary to create a compact and homogeneous carpet, causes the grass to suffer a recurrent loss of active leave surface, of water and of stored up glucidic supplies and nutrients, finally causing a weakening of the roots, while at the same time causing the development of runners and rhizomes. Under these conditions it will be necessary to carefully control that the nutrients and water applied are adequate.

It must also be kept in mind that a long term crop, in which there are no rest periods, brings about the appearance of parasites and diseases, which must be dealt with permanently, while the soil itself cannot be sanitized. The products to be used are also subject to limitations, as it will only be possible to use the phytopathological products registered for use in park and garden areas.

This feature occasionally will not only bear upon the farming needs, but also the performance requirements during the year, as more and more there is a demand for a lawn in acceptable conditions for longer periods in the year or the season.

Decorative requirements

Unlike most of the crops, in which the performance can be appreciated as a given output of fruits, flowers or vegetal produce, in a golf course the aim is to obtain an ornamental return. This factor encompasses the variables of homogeneity, denseness, colour, consistency and smoothness, which in turn depend on the growth (or regeneration) potential, health conditions, and damage caused by use.

The requirements demanded from a grass crop and the evaluation of the extent to which they are met depend on the field, its geographical position and the demands of the members, clients, etc., and within the same field we may find different degrees of requirements, depending on the situation of cultivation: greens, antegreens, roughs, fairways or tees.

2. IRRIGATION IN GOLF COURSES

2.1. Water needs

The need for water in a lawn will be conditioned by the weather conditions (temperature, wind speed and relative humidity, and length and intensity of sun radiation), and the transpiration capacity of the plants themselves.

The PET (Potential Evapo Transpiration), which is defined as the transpiration that a herbaceous unbroken and uniform cultivation of gramineae, 8 to 15 cm high, produces without being limited by the level of watering, is an indicator of the amount of water needed by the cultivation. Besides, the actual transpiration effected by each species holds a steady relationship with a constant of the cultivation Kc which, multiplied by the PET gives the Evapo Transpiration of the species. The PET can be immediately known by the correlation with an Evaporimetric Tank, or by means of formulae which release the information according to the weather variables (Penmann, Blaney & Criddle, Thornthwaite, Turc,…). There are also computerized systems which let you know the PET on the spot and for a given period according to the information received from a local weather station. Several official agencies publish regularly the PET information for different periods in each weather season.

In the case of the grass species most frequently used in golf courses, the Kc constant fluctuates between 0.6 for the hot climate species and 0.7 to 0.8 for the cold climate species.

2.2. Poor irrigation and survival irrigation

Watering a grass cultivation below its needs may be useful to save water, but this action may slow down its growth and jeopardize the recovery of areas especially damaged by use, whereby it is not recommended to be used in greens nor in tees.

We talk about poor irrigation when its amount is below the needs of the grass but not so bad as to produce stress. Generally speaking, a poor irrigation can be something like 70-85% of the required needs.

We talk about survival irrigation when we supply the grass enough water not to endanger its future recovery when the supply conditions are back to normal. Since this notion implies the loss of the ornamental features of the lawn, and make it more exposed to ailments and diseases, it is exclusively applied at times when water is exceptionally scarce. The PET percentage which is being considered under this hypothesis goes from 20 to 40%, and depends on the species and its adaptation.

It must also be kept in mind that the practice of poor irrigation policies must be carefully controlled in order to avoid producing problems of salinity which are difficult to solve .

2.3. Distribution systems

The distribution systems in a golf course must supply water with a high level of consistency. This factor may have a special importance:

- On sandy substrata where water filters down at high speed and there is “little capilar or horizontal behaviour”. In these cases the soil will not produce any homogenizing action on the water distribution.
- On superficial soils, with little depth, and in general soils with a reduced holding capacity.
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- In high frequency programmes or with reduced watering amounts.

2.4. Principles for the layout of an irrigation system

To make the layout of an irrigation system in a golf course the following features must be kept in mind:

- Water needs in a given period of time
- Water storage capacity of the substratum
- Needs for leaching out salts
- Losses
- Natural supplies: rain water
- Recovery of leached out salts or of runoffs

Water needs in a given period of time

Will determinate supply possibility or storage need:

- Potential evapotranspiration according to areas (climate factor)
- Features according to species and cultivars (variety factor): the cultivation Kc is a constant which relates the PET with the actual consumption of the same under equivalent weather conditions. This value may be considered about 0,7 to1,0 for most species
- Actual depth of root system
- Frequency and amount of natural rain

2.5. Irrigation planning

- Field capacity and maximum stress which can be borne by the cultivation with acceptable loss of the ornamental results

- Soil features definition and capacity (usable water)

- Depth of root system: it depends on the soil conditions (ventilation, quality and structure), on how the cultivation is run (if the irrigation is very frequent the rooting system will develop near the surface), and it is also limited by the special features of every species and cultivar

2.6. Further considerations

- Need for leaching out salts (depending on the salinity of soil and/or water)
- proneness of cultivation to diseases related with water (asphyxia, fungic infections), presence of pathogens and their ability to start a disease process depending on environmental parameters (R.H:, water from condensation or precipitation, exposure time) and on phenological parameters (cuts or injuries caused by transit, water stress, etc.)

- time limits and/or temporary limits of the irrigation cycles. In the season when the golf course is used most, which will probably be the same as when there is the higher water demand, the irrigation work will have to be done at those times when there is no golfing activity. It will also be necessary to foresee the incompatibility of sprinkling the lawns while other farming work is taking place (such as phytopathologic treatments, cuts, top dressings, new sowings and new plantings, etc.)

    - These limitations make it necessary to apply large amounts of water simultaneously, limited in each area by the speed of infiltration of water in soil, by the appearance of runoffs and by the available supply and storage in each cycle

2.7. Need for leaching out salts

The increase in the water tension on soil because of salinity usually depends on the fact that the supply of salts through the irrigation water is not balanced by leaching out the same salts through the drainage water. In fact, if the field capacity is not exceeded, an irrigation with amounts of water equivalent to the accumulated transpiration implies a salts buildup and the progressive increase of tension. These effects can intensify their action and results if a poor irrigation policy is applied.

Salinity increases naturally in periods with less pluviometry or greater transpiration, and it decreases in the rainy season or when there is a better balance of rain and transpiration.

The need to leach out salts, starting with a soil with an acceptable salinity degree, will be such that, for a given period of time, the volume of drained out water must contain the same volume of water supplied by irrigation. The quantization of the irrigation volume X the irrigation conductivity and drainage conductivity will allow to evaluate the drainage volume needed.

However, drainage not only washes out the salts which cause an increase of the retention potential of soil, but also of the necessary nutrients for the crop development. This will have to be kept in mind in order to increase the supply of nutrients, especially Nitrogen, because of its high solubility.

The amount of water needed depends on its quality. The higher the salts level the higher the washing out needed. Some authors suggest an evaluation of the water excess with which we must work preventively in order to avoid salinization:

$$\text{Washing needs \%} = \frac{\text{Conductivity of irrigation water} \times 100}{\text{N} \times \text{max. assumable Conduct.} - \text{Irrigation Water Conductivity}}$$

Where N is a number between 2 and 5 depending on the consulted source.

The salts tolerance of some of the species used can be established between 6 and 10 mMhos/cm. An inadequate leaching out may damage the yield of the lawns, but an excessive leaching out will drain valuable nutrients. Interpreting the analysis carried out in comparison with those effected in the same season in previous years will let us know if the leaching out effected along the year has been sufficient, and if it is necessary to increase the established percentages of leaching.

2.8. Irrigation systems in golf courses

The need for large amounts of water and the relatively shallow soils available have brought about a policy of daily watering in summer, which must be carried out exclusively by night in order not to interfere with the sport practice. The dimensions of a golf course above 40 hectares, with 7 mm daily waterings, will need a daily amount of 2,800 m3, which means a water flow of about 280 m3/h irrigating 10 hours daily.

In order to supply water more uniformly and to avoid these supply variations, lakes can be used as storage to regulate the water supply, being at the same time an attraction for players and a landscape feature. By locating them in the lower parts of the golf courses they will also receive the rivulets produced by rain.

The distribution of water in the field is carried out through a primary network from which secondary networks are derived, fed by electrovalves which supply the sprinkler heads. The distance between sprinklers ideally must be that which allows to cover easily the expected surface. The savings obtained through the installation of a system in which the overlap between consecutive sprinklers is not total are spent in a higher water consumption, because the irrigation of an area must be made in terms of that part of the area which receives less water. These savings are also spent in a higher fertilizers consumption, greater pathogenic occurrences and higher spenditure in products, while sprinkling for the time needed in the area which receives less rainfall, the area with greater rainfall is watered in excess, thereby sweeping away products and impoverishing the soil. A heterogeneous irrigation system produces a heterogeneous nutrition level of the soil, which will be greater in the distribution of Nitrogen in the short term.

These factors are more important where there is need for leaching out and when sewage water is used. In this case there may be also an accumulation of products harmful to the cultivation.

The final element of irrigation is usually the sprinkler, either an impact or a turbine sprinkler. The use of different nozzles helps to homogenize irrigation when in the same area concur circular and sectorial sprinklers. Usually sprinklers have a range of 18 to 25 m, with consumptions of 3 to 8 m3/h, and actual rainfall of 20 to 30 mm/h with a spacing between them equal to their own throw radius. The use of systems with an electrovalve for each sprinkler allows an individualized control according to the output and the special needs of every area.

Pumping station in a golf course

To have a correct control of the water supply it is not advisable to follow exclusively the information supplied by the manufacturer, as the working conditions of each sprinkler are different, especially with respect to the pressure received at the basis, and the conditions may even vary depending on the activity of more or less areas simultaneously and their relative position in the field. A better information can be obtained by means of the direct measurement of rainfall, which may help in programming and correcting the inner heterogeneity in the same area by regulating the sprinklers.

3.1. Nutrients

3.1.1. Nitrogen

Because of its importance as a limiting factor of metabolism and proteinic synthesis, this element is responsible for colour, growth rate and therefore regeneration of the lawns. Lack of it produces yellowing, slowing down of growth, rooting and stem branching. Its excess produces dramatic results in the cultivation of grass, such as formation of thatch, excessive growth, weakening, a greater sensitivity to physiological and pathological alterations, and a deficiency in the availability of other nutrients.

High levels of nitrogenated fertilization increase the consumption of carbohydrates in summer and reduce their buildup in autumn.

The high solubility of nitrogen, especially the nitric one, helps both to leach out in depth and to have it quickly available for cultivation when fertilization is carried out, which makes it difficult to handle this element in this particular cultivation with shallow roots and frequent waterings. It has also been found that there is dissolved nitrogen in the waters of surface rivulets.

This particular problem has lately caused the use of nitrogenated, slow action fertilizers to spread, being these high cost products in which a portion of the nitrogen supplied is at the disposal of the plant after a period which goes from a few weeks to some months.

We may find several sources of nitrogen for fertilizing, depending on the rate of solubility or release of the same.

Even if plants can only absorb nitric nitrogen NO_3, the classical handling of solid nitrogenated fertilizers requires the combination of different sources in order to obtain a gradual release into the soil. The sources of inorganic nitrogen show the following features:

- A quick answer. Immediate availability to the plant
- A minimum dependence on temperature
- Little persistence in soil (especially the nitric formulae)

The ammoniacal nitrogen NH_4^+ is not essential for cultivations as it is not directly absorbed and on the other hand it can hardly be retained in the sandy substrata with a low CEC.

3.1.2. Phosphorus

Phosphorus has a direct relationship with the development of the root system, and its low solubility is well known in the soil solution and its trend to immobility, which is increased with the pH level. Traditionally it has been used in the starting fertilizations, which in long term cultivations lack interest because of the mentioned immobility.

The low mobility of phosphorus in soil, and its tendency to be immobilized, make it difficult for this element to be available in depth when it is spread under solid form on the surface. It has been tried to make it available by locating it in depth through ventilation holes.

The starting application of great amounts of phosphorus are not enough to guarantee the availability levels requested by the grass, and it is necessary to make frequent applications of P if we want to keep a reasonable nutritional level. High pH levels may increase the need to fertilize with this element to balance its loss through immobility.

3.1.3. Potassium

Together with the preceding two elements, potassium makes up the group of macronutrients called "NPK" mainly used by plants, it works on many levels in the plant metabolism (carbohydrates synthesis, proteinic and aminoacids synthesis, reduction of nitrates, breathing processes…) and its deficiency produces a weakening of crops at different levels: physiopathologies (cold, heat, mechanic aggressions), proneness to disease and slowing down of growth.

The root growth increases in autumn and winter, with temperatures above 0ºC. Supplying P and K at this time encourages this process which in the long term improves resistance to drought and helps the appropriation of nutrients.

3.2. Fertilization in Golf Courses

Fertilization in a golf course may be based on the extraction carried out by the crop, the drainage and rivulets losses, and the immobility losses (in the case of phosphorus) or losses caused by nutritional conditions which are maintained in the soil solution. This may be found out through an analysis.

The first step to fertilize a golf course is to determine the soil fertility. In order to keep an acceptable growth, enough fertilizers must be supplied to cover the needs of each cultivation. The soil analysis allows to find out nutritional flaws, to evaluate excesses or imbalances between nutrients, and also pH chemical conditions, salinity, sodium contents, the presence of heavy metals and the evaluation of the compound of cationic exchange.

It must be kept in mind that we will find different cultivations in the same field, and a very special attention shall be given to the greens. Samples shall be taken at depths where plants have a greater root development. The decisions according to the analysis results shall be taken following the principle of the sufficiency level of available nutrient (SLAN). The sufficiency level of available nutrients is based on the concept of decreasing outputs. As the measured level becomes higher there is an increase of the amount of fertilizer needed to produce an answer, and for the same increase in the fertilizer supply the answer will be lower. The available information is usually based on the results obtained for extensive and horticultural crops, and cannot be directly applied to cultivation of garden lawns, where the response cannot be measured exclusively as a production of dry product or crop variables.

The concept of maintenance of a given portion of the compound of cationic exchange (BCSR Basic Cation Saturation Ratio) has also been discussed but there doesn't seem to be a general agreement in the application of this concept. It is based on previous studies where it is suggested that an "ideal" soil should have a cations distribution of 65% Ca, 10% Mg, 5% K and 20% H. On the other hand, in the specific case of greens based on sand, with a low level of cationic exchange, possibly the K percentages are not sufficient and below the USGA specifications.

After the soil fertility levels have been fixed to the appropriate values, it will be necessary to maintain a balance and availability of nutrients during a much longer period than for any other herbaceous cultivation and with an in depth action made difficult by its continuity and its level of total ground coverage.

Fertilizers recommendations vary enormously depending on the bibliography, and will depend on the species and variety cultivated, the soil and weather features of each golf course, and the season's weather conditions. It is difficult to establish a single fertilization model, and the lawn's answer to previous fertilizations will help the greenkeeper to fix his own goals for the cultivation, which will imply a continuous, non excessive growth, a good colour, and the ability to resist diseases and physiopathologies.

A suitable balance for conventional fertilizers may be about 3-1-3, or 3-1-2, establishing the need for nitrogen between 100 and 200 UF/year, which may be increased when the cultivation is in a sandy soil. In areas of very intensive use (tees and greens) we have found programmes of up to 350 FU/year! In theses cases the level of P_2O_5 and K_2O is supplied in a much lower proportion. This decrease in the recommendations of phosphorus and potassium fertilizers, when nitrogen is being supplied in such high doses, gives an idea of the great amount of nitrogen which is lost (leaching out, surface runoffs,…) with these programmes.

The fertilization programme must envisage the whole year supplies, with peaks of higher supply when there is a higher growth rate: March-April. It is necessary to distinguish between handling cold season and hot season varieties, and also the field position, in order to decide the length of the programme. Usually, with the only exception of fields located in cold areas, this programme must foresee supplies the whole year round, and it is advised to make fortnightly applications during the growing season, and scarcely monthly applications in the cold season.

Recent studies in Poa pratensis, Agrostis stolonifera and Festuca arundinacea have pointed out the need to know the plant physiology all along the cultivation cycle: multiplication, carbohydrates storage and development of leaves, rhyzomes or roots, do not take place uniformly during the year, and the fertilization and its balance will have an influence either helping or hindering normal vegetal activity.

3.3. Ground acidity in golf courses: pH

The pH value, which goes from 1 to 14, indicates the acidity degree of a solution. The lower the figure the higher the solution acidity.

The pH value is one of the most decisive variables of the soil chemical and biological reactions. It has an influence on:

- Availability to the plant of existing nutrients. This bears upon the fertilizers efficiency (it is higher if the pH is right)
    - An excessive availability of Aluminium (Al) and Manganese (Mn) with a very low pH may bring about toxicity
    - Very high pH may cause a deficiency in Phosphorus (P), Iron (Fe) and Manganese (Mn).
- Microbial activity
    - The bacterial nitrification process takes place between pH 4 and pH 9, and reaches its highest between pH 6 and pH 7
    - pH has an influence on the stratification of organic matter in soil and the creation of thatch. pH levels below 6 interfere in the bacterial activity which is necessary for decomposing thatch, which may worsen this problem to be found in many fields
- The development of vegetal species (each species and variety has suitable values for its development)

In turn the pH level depends on the fertilizers supply and their reaction in contact with the irrigation water, which provides ions in a continually and in a selectively cumulative way .

pH constant value can be read by means of pH probes inserted in irrigation pipe

3.3. Sodium contents and Salinity

This concerns the unfavorable action of Sodium on the soil structure. The process implies the substitution of divalent cations (Calcium, Magnesium) in the structures which make up and keep together the soil through a monovalent cation Sodium, which has no cohesion power. This causes the soil aggregates to break up, which implies a parallel reduction of the infiltration range of water and brings about the occurrence of root asphyxia.

The presence of Calcium and Magnesium reduces this harmful effect whereby this feature in a solution is evaluated according to the relative amount of Sodium with respect to the sum of the divalent elements Calcium and Magnesium. We may define the Sodium Absorption Relationship (SAR) according to the following formula:

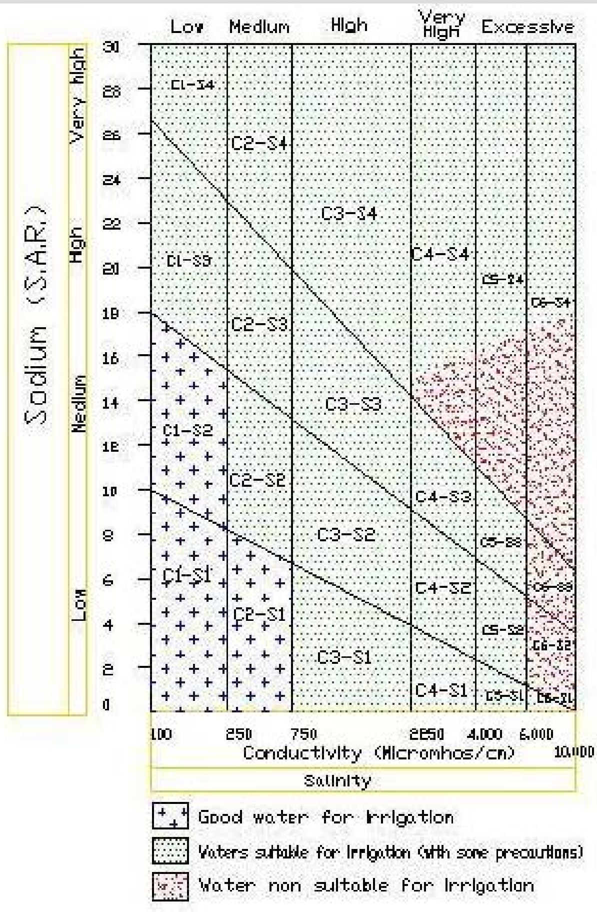
$$S.A.R. = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where ions are stated in miliequivalents/litre.

According to this parameter, as long as water is not saline, it is classified as suitable under the following groups:

- S1: (up to SAR=10). Low sodium contents. Suitable for most soils.
- S2: (10 < SAR < 18). Middle contents. Suitable for organic soils or highly permeable, thick-textured soils.
- S3: (18 < SAR < 26). High contents. Risk of buildup in soil. It is necessary to correct with organic matter and chalk.
- S4: (SAR > 26). Unbearable sodium contents for water to be used in irrigation.

However, the suitability for irrigation of water with a sodium contents depends also on the soil and the total salinity of water. The most common evaluation method is Riverside's, which classifies water in 16 groups according to SAR and Conductivity, as can be seen in the following graph:



4. Fertigation in Golf Courses

Fertigation consists of the simultaneous supply of water and nutrients by means of an irrigation system. It also foresees improving the irrigation water by controlling chemical parameters (pH).

4.1. Advantages of fertigation

- ✓ Greater stability over time in the availability of nutrients, without peaks, nor excesses nor moments of low fertility of soil
- ✓ Greater availability of supplied nutrients, as it is possible to establish optimum pH levels for their absorption
- ✓ Immediate reaction to fertilization, as the nutrients are supplied to the soil already dissolved
- ✓ Tapping the leaves ability to absorb nutrients in case of sprinkling or diffusion irrigation
- ✓ Reducing fertilizer loss through washing out (drainage) or through surface rivulets. Lower environmental impact through pollution of surface water (lakes, streams…) and of underground aquiferous layers
- ✓ Reducing fertilizer loss through immobility. For example, applying phosphorus as a maintenance fertilizer on the levels needed by the plant avoids the immobility which in large proportions damages soils with a neutral or alkaline pH
- ✓ Establishing much more frequent fertilization programmes without upsetting the costs in the system or in the distribution work
- ✓ Quickly and effectively establishing different formulae according to season, development and occurrences of the season. For example, it is possible after the rain to apply in a higher degree those nutrients which are more soluble, or to correct growth trends by reducing one single nutrient (for example, N)
- ✓ A rational use of lower quality or recycled water (as for example by adding Calcium and Magnesium in high sodium water).
- ✓ An economic saving in the use of fertilizers (it is not necessary to supply slow release fertilizers, and liquid or soluble conventional fertilizers can be used).
- ✓ A lower soil compression caused by transiting vehicles or maintenance workers.
- ✓ Cost reduction in the distribution of fertilizers and phytopathological products.

- ✓ No particles which the mowers might pick up
- ✓ No pellets on the surface, which golfers don't like to see.

4.2. Drawbacks of fertigation

- ✓ Requirement of qualified staff to control fertigation.
- ✓ Requirement of injection and control equipment for fertigation, and of storage facilities for the fertilizer solutions.
- ✓ Longer irrigation periods: the application of fertilizer, for example in the rainy season when it is not necessary to irrigate the lawns, will imply an increase in the irrigation time, simply to act as vehicle for the products supplied. This aspect becomes worse when undersized dosing equipments are used.

4.3. Periodicity of the fertigation cycles

At the beginning of this practice it was customary to apply fertilizer in single operations, every fortnight or every month. This practice was the result of adapting the usual models for the new system of application of granular products and it implied an excessive growth as a result of the operation, as it happens when you apply fertilizers the traditional way.

The fertilization strategy with solids is related to the associated cost of their distribution on the field and the difficulty of handling small quantities to be spread on large extensions. With fertigation it is not a matter of cost operation as it is carried out without using manpower, the machinery costs will be fixed for the whole season and the energy consumption is irrelevant with respect to the consumption necessary for the operation of the irrigation systems. Besides, distributing small quantities will not entail any problem, as it will allow to use smaller sized equipments.

The fertilizer distribution in all the irrigation cycles allows to obtain a uniform nutritional degree during the season and avoids growth peaks, thereby reducing maintenance needs (mowing), reducing also losses through washing out and consumption, and avoiding a lush growth which would imply a higher phytopathological risk. Besides, dissolving the fertilizer in a large water amount allows the use of lower flow injectors.

4.4. Dosage of fertilizers

Operating fertigation implies knowing the cultivation needs in each season, both with respect to each nutrient and to water. When it is decided which products are going to be used, we can establish the dissolution degree for each fertilizer, depending on its concentration and the volume of water in which it will be dissolved.

When the irrigation water is used as a vehicle to supply fertilizers dissolved in it, we must make sure that the fertilizers reach the plant without having precipitated or being immobilized. To this end it is essential to know the irrigation solution pH and to correct it if it is not suitable. The whole of the nutritious elements is stable and available at pH 6-6.5, which is an acceptable pH level for all the species used in the golf courses.

Dosage of different products can be adjusted along time to adapt to the different nutritional needs of the lawns during the season. It will have to be adjusted also according to the water volume in which it will be distributed. In fact, for two periods with the same nutritional requirements, the product will be applied with a higher concentration in the period which has a lower irrigation possibility.

Dosage of products to improve the water quality, such as magnesium and calcium salts to control the sodium contents, will have to be effected in accordance with the analyses of the irrigation water, which will indicate a fixed proportion between irrigation flow and injection flow. In this case it will not depend on the volume applied during the time period.

To reach a uniform growth rate and to avoid peaks and slowingdowns or nutritional imbalances, the best thing would be to fertigate every day, or in each irrigation cycle. This will bring about a saving of fertilizers, of mowing operations and of phytopathological disorders, and does not compel to have injectors for large flow rates.

The maximum concentration of the fertilizing elements in the tanks may be limited by the reaction and precipitation of unmixable products in high concentrations. In practice, it will be necessary to envisage the installation of three fertilizer tanks for the macroelements Nitrogen, Phosphorus and Potassium, another for the solution of microelements, and finally another one for the acid to be used to control the pH. Eventually it may be useful to have other small tanks available for phytopathological products, moisteners, calcium, etc. All of it will depend on the strategy foreseen in the treatment.

The amount of each product to be injected will depend on the calculation effected of the need of every fertilizer divided by the foreseen volume of irrigation. There is a possibility of an independent control of each fertilizer if it is injected by means of independent pumps, or by means of different heads for the same pump, if we may control the output of each of them independently. The work pressure of the dosing pumps must always be higher than the pressure in the network in which the injection is to be carried out.

4.5. Calculation of fertigation in one given period

Example of calculation of fertigation for fertilizing a field in one given month.

The available data are:

- Month: June
- Irrigation: 20 5 L/m2 watering during the month (total 100 L/m2)
- Extension of the field to be irrigated: 40 hectares
- Water consumption per watering: 2.000 m3
- Monthly water consumption: 8.000 m3
- Maximum watering flow: 250 m3/h
- Average watering flow: 220 m3/h

Foreseen nutritional needs during the month:

- 25 Kg/Ha N *x 40 Ha* *= 1000 Kg N*
- 10 Kg/Ha P_2O_5 *x 40 Ha* *= 400 Kg* P_2O_5
- 15 Kg/Ha K_2O *x 40 Ha* *= 800 Kg* K_2O

The products which have been chosen are:N-32, monoammonium Phosphate and Potash acid solution at 15%. The percentages of the chosen products are:

- N-32	32% N	
- Monoammonium Phosphate	12% N	60% P_2O_5
- Acid Potash solution		15% K_2O

The products amounts to be used are established depending on the nutritional needs and their contents:

Monoammonium Phosphate ($NH_4H_2PO_4$)

$$400\ Kg\ P_2O_5 \times \frac{100\ Kg\ NH_4H_2PO_4}{60\ Kg\ P_2O_5} = 667\ Kg\ NH_4H_2PO_4$$

... which we dissolve at a rate of 200 g/l in a total of...

$$667 \text{ Kg Monoammonium Phosphate} \times \frac{1 \text{ l solution } NH_4H_2PO_4}{0,2 \text{ Kg } NH_4H_2PO_4} = 3.335 \text{ L main solution}$$

Which besides will supply...

$$667 \text{ Kg Monoammonium Phosphate} \times 12\% = 80 \text{ Kg N}$$

...which will be deducted from the Nitrogen needed

$$(1000 - 80) \text{ Kg N} \times \frac{100 \text{ L N-32}}{32 \text{ Kg N}} = 2.875 \text{ L N-32}$$

... which will be dissolved at the rate of 200 g/l in a total quantity of 3.335 L solution

Finally, the amount of Potash acid solution to be injected will be...

$$800 \text{ Kg } K_2O \times \frac{100 \text{ L A.P.S.}}{15 \text{ Kg } K_2O} = 5.333 \text{ L Potash Acid Solution}$$

Therefore, the fertilizer quantities to be injected will be:

$$\frac{2.872 \text{ L de N-32}}{160 \text{ injection hours}} = 18 \text{ L/h N-32}$$

$$\frac{3.335 \text{ L Monoammonium Phosphate } (NH_4H_2PO_4 \text{ al } 20\%)}{160 \text{ injection hours}} = 21 \text{ L/h } NH_4H_2PO_4 \text{ at } 20\%$$

$$\frac{5.333 \text{ L A.P.S. at } 15\%}{160 \text{ injection hours}} = 33 \text{ L/h Potash Acid Solution at } 15\%$$

4.6. Considerations on using recycled water

Water is considered a limited resource which makes it difficult to obtain, this means that golf courses in many places are compelled to use water from purifying plants. The situation of the plants which purify sewage, located near the large conurbations, has improved their conduction to the golf courses which are near towns or in tourist areas, which are the most concerned by this situation. Grass is a much more effective filter than other crops, besides, not being for food consumption, the sanitary considerations are less important, and their use helps to build up the image of an activity which respects the environment. Besides, even if usually the use of this sort of water is felt like a complication for cultivation, it saves costs in handling the golf courses (as its cost is lower) and avoids the risk of restrictions when there is a shortage of it, which usually happens when there is the greatest need for the lawns.

Recycled water contains in solution some beneficial substances, especially Nitrogen and Phosphorus, which will have to be kept in mind in order not to apply these nutrients in excess. It is also important to know if there are toxic ions, such us Chlorine or Sodium, and even which antagonisms or interplays may take place among the ions which are already there and those which may be added by means of the fertigation process, or those which will be found in the soil. The destructuring action of Sodium will have to be fought by administering Calcium and Magnesium salts.

A good choice of the grass varieties which resist better to pollutants and chemical conditions of the water will allow an easier handling and will avoid greater risks. It is advisable to cultivate grasses to be irrigated with sewage in highly draining substrata, even better if they are sandy and with a low level of cations exchange, in order to avoid the accumulation of toxic elements.

It is advisable to analyze regularly the water, plants and soil in order to spot possible accumulations or deficiencies, and to correct in a suitable manner the fertilizers supply.

The excess of nitrogen may be reduced by storing it. In fact, under conditions of an alkaline pH, the ammonium ion NH_4+ is transformed into ammonia and evaporates. This loss concerns also urea which is spontaneously converted into ammonium.

Salinity: the same as the salinity induced by not recycled irrigation water, this causes an excessive irrigation. However, if better quality water is available, it can be mixed in proportions tolerated without a need for high leaching levels.

5. INJECTION DEVICES FOR FERTILIZATION IN GOLF COURSES

Because of the features of the most frequent filtration and impulse heads in golf courses, and their possible performance with very different flow ranges, it is necessary to have available an equipment to adjust their injection capacity.

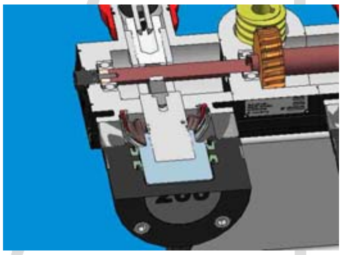
Since the heads usually work at pressures over 7 bars, and with flows in maximum ranges of 200 to 600 m3/h, it is not advisable to use systems based on Venturi, since that would lead to a loss of at least 30% of pressure, or to an oversizing of a system which is in itself already very high-priced, and which would compel to a further control of the amount of each product being injected.

The use of hydraulic injection pumps is also not advisable, because these sort of dosing pumps loose some of the flow, which is not always sustainable, and these pumps are not easy to control in case of different or variable flow rates, or either they work but with a loss of their fill.

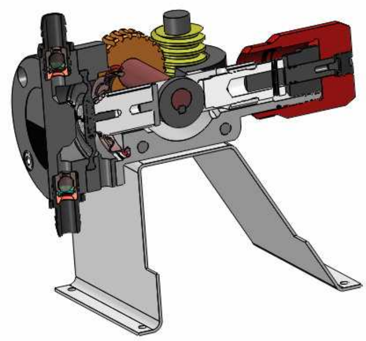
5.1. Electric dosing pumps

The most suitable dosing pumps for products in great flows under pressure are the equipments of active injection. In practice all the active injection systems of fertilizers use electric motors, which makes the injection control very reliable.

Within these systems, at present are used basically two sorts of injection pumps: piston pumps and diaphragm pumps.



Piston pumps: Injection can be controlled in a precise way by adjusting the piston stroke to a given percentage or through the injections frequency. They are high precision pumps, since the volume moved by the piston in its travel does not depend on the pressure in the network, nor on the product density or viscosity.



Diaphragm Pumps: here also the piston stroke and the injection frequency can be adjusted, however its use is limited to low pressures and flows, since the diaphragm deformation may depend on the physical variables, and most especially on the network pressure.

However, since there is no displacement between the surfaces, the cylinder chamber is absolutely watertight, and this makes it an ideal device for the injection of very corrosive, dangerous or highly-priced products, where, in order to attain a zero loss of product a number of collars are used. Applications where the dosage will be controlled through chemical features, such as the conductivity control or pH (acids injections) are not harmed by the precision loss caused by the membrane deformation.

ITC has a range of electropumps for fertigation and chemigation suitable for these operations.

The MULTIFERTIC® range allows the injection of up to 4 different products through a multihead pump (it can be automatized by means of a servomotor) independently hand-controlled for each head from 0 to 100% of its nominal flow.

It is manufactured for nominal flows of 25, 50, 100, 200, 300 and 500 l/h at pressures of up to 15 bar. The same electropump can combine different sorts of head with different flow outputs, which allows to work accurately with different injection flows at the same time.

The MULTIFERTIC® injection modules are available in different materials:

Piston modules

Piston	Cylinder	Flows
Polypropylene	Polypropylene	25, 50, 100, 200, 300 & 500 L/h
Ceramic	Polypropylene or stainless steel	25, 50, 100, 200 & 300 L/h

Diaphragm modules

Diaphragm	Cylinder	Flows
Teflon	Polypropylene	25, 50, 100, 200 & 300 L/h
Teflon	Stainless steel	25, 50, 100, 200 & 300 L/h

Performance

Piston modules

Flow (L/h)	Pressure (bar)
25	15
50	15
100	15
200	8
300	5
500	3

Diaphragm modules

Flow (L/h)	Pressure (bar)
25	10
50	10
100	10
200	6
300	4

A common application of MULTIFERTIC® dosing pump is the simultaneous and proportional injection of several products. For example, we can inject at the same time two different fertilizers by means of two polypropylene piston heads, sulphuric acid by means of a diaphragm on an stainless steel head, and iron chelates by means of a diaphragm on a polypropylene head.

The **ELECTROFERTIC 2000®** range has pumps with one and two injection heads for large flows: 500, 750 and 1000 L/h per head, up to 12 bars, wherefore it is suitable to cover the needs of fields where large injection flows are needed.

Performance of ELECTROFERTIC 2000® electric dosing pump

Single injection head models

	Injection pressure	
Nominal flow	Low pressure model	High pressure model
500 L/h	9 bar	12 bar
750 L/h	5,5 bar	8 bar
1000 L/h	3.5 bar	6 bar

Double injection head models

	Injection pressure	
Nominal flows	Low pressure model	High pressure model
500 + 500 L/h	9 bar	12 bar
750 + 500 L/h	5,5 bar	8 bar
750 + 750 L/h	5,5 bar	8 bar
1000 + 500 L/h	3,5 bar	6 bar
1000 + 750 L/h	3,5 bar	6 bar
1000 + 1000 L/h	3,5 bar	6 bar

Because of the irrigation complexity in golf courses, the products injection will be carried out by means of equipments able to control the injected fertilizer amount in accordance with a proportion which has been established in advance by the greenkeeper. This requires knowing the instant flow, which may vary depending on the areas which are working. We may know this instant flow through the use of a high frequency flowmeter. We can also make this injection flow depend on this parameter, by using a controller to feed the pump by means of an inverter.

Mentioned flows all refer to a three-phase dosing pump feed 230/460 V at 50Hz. Please notice all dosing pumps MULTIFERTIC® and ELECTROFERTIC® 2000 may be fed at 60 Hz, so that maximum injection flow will increase up to a 20% over flows shown in the above charts.

ITC electric dosing pumps can be fed at a wide frequency ranges, which make them particularly useful when regulating an injection by means of controllers through inverters.

The installation of an additional ventilation is important if the pump is going to be fed through an inverter, to guarantee its correct ventilation even with very low motor revolutions.

5.2. Establishing the size of dosimeters

There are several factors to be kept in mind when establishing the sizes of the fertigation heads. A complete calculation can be effected taking into account the foreseen monthly or fortnightly needs of fertilizer during the year, besides the supply of water which will be supplied to the crop.

It becomes clear that in some periods the irrigation need will be higher and we shall then inject a lower proportion of fertilizer, and at other times when less water will be needed the fertilizer will have to be more concentrated in the irrigation solution, and larger flow injectors will be needed. It must also be kept in mind that the fertilizers concentration in the irrigation flow will be limited by their solubility and by the toxicity they might introduce in the crop.

The sizing of the dosing pumps may be modified even by the storage temperature of the main solutions. Potassium nitrate, which has a solubility of 370 g/L at 25ºC, at 5ºC will only be dissolved at the rate of 180g/L.

In our experience we find that generally speaking it may be sufficient to have a sizing which guarantees the injection of fertilizers in a global proportion of 1.5 to 2º/ºº of the irrigation flow .

The number and relative capacity of the tanks containing fertilizers will depend on the strategy to be adopted. Simple fertilizers are usually the most profitable and all-purpose option, as it allows to change their proportions at any time without any need to empty the tanks contents, but it requires a greater number of tanks. As a general idea, we may establish one dosing head and at least one tank for each one of the following nutrients.

Fertilizers	Sizing *L of injection/ m3 irrigation*
- Nitrogen	0,5 (1)
- Phosphorus	0,5
- Potassium	1(2)
- Calcium (in sodium waters)	Variable (3)
- Microelements	0.2 L /m3
- Acid	Variable 0.15 to 0.30 L/m^3 (4)

(1) If we are going to use fertilizers with a concentration below 30%, this value should be increased proportionally. It must also be kept in mind that in lengthy rain periods the influence of nitrates drainage may imply higher amounts of this element with respect to P and K.

(2) Potassium usually requires the highest dosage, unless you apply some of the Nitrogen as Potassium Nitrogen.

(3) It depends on the solubility or on the amount of Sodium correcting product and on the necessary correction, which in turn will depend on the SAR and on the soil type. For example, adding 1 meq Ca2+ per liter of water to a product with a 12% concentration implies a dosage of 0.14 L/m3.

(4) The acid dosage cannot be foreseen in advance and depends on the salts combination to be found in the irrigation solution and on the effect of the macronutrients fertilizers. An approach to it can be found in graphs in addenda. Reducing 1 point pH by the injection of Nitric Acid at 40% in a flow of 200 m3 may mean an approximate consumption of 15 to 30 L/h of acid solution. The greatest amounts will be needed in general in bicarbonate waters and in any case there is always the possibility of choosing the acid concentration which is more suitable to the chosen head. Generally speaking, introducing heads of up to 100 to 200 L/h is usually enough to control the pH in the most usual flows in golf courses, which are usually below 500 m3.

Even if the most appropriate sizing of heads can be studied, according to the strategy to be applied and the analysis of the irrigation water, an approach could be as follows:

Irrigation flow m^3/h	Injection requirements in L/h						
	N	P	K	micros	phytos	acid [(1)]	acid [(2)]
200	100	100	200	40	40	30	60
250	125	125	250	50	50	37,5	75
300	150	150	300	60	60	45	90
350	175	175	350	70	70	52,5	105
400	200	200	400	80	80	60	120
500	250	250	500	100	100	75	150
600	300	300	600	120	120	90	180
700	350	350	700	140	140	105	210

From the above it can be inferred that, if we take into account the range of nominal flows of the ITC injection pumps, which can be increased up to a 20% if they are fed through a frequency variator, the smallest heads to be used will be the following, depending on the network pressures:

Injection up to 8 bar

	Nominal flow of Head in L/h						
Irrigation Flow	N	P	K	micros	phytos	acid [(1)]	acid [(2)]
< 200 m^3/h	100	100	200	50	50	50	100
< 250 m^3/h	100	100	200	50	50	50	100
< 300 m^3/h [(3)]	200	200	***500***	50	50	50	100
< 300 m^3/h	200	200	2x200	50	50	50	100
< 350 m^3/h	200	200	***500***	100	100	100	100
< 350 m^3/h	200	200	2x200	100	100	100	100
< 400 m^3/h	200	200	***500***	100	100	100	100
< 500 m^3/h	***500***	***500***	***500***	100	100	100	200
< 600 m^3/h	***500***	***500***	***500***	100	100	100	200
< 700 m^3/h	***500***	***500***	***750***	200	200	100	200

(1) Assuming an adjustment of 1 point in pH range with nitric acid at 40%.

(2) Assuming an adjustment of 2 points in pH range with nitric acid at 40%.

(3) Should monopotassium phosphate be injected as a source of Phosphorus, or Potassium Nitrate as a source of Nitrogen, a single head of 200 L/h for K could be used.

(4) The flows rates inside a frame refer to Electrofertic 2000® models, all the others refer to heads of the Multifertic® dosing pump.

Injection up to 12 bar

	Nominal flow of Head in L/h						
Irrigation flow	N	P	K	micros	phytos	acid (1)	acid
< 200 m^3/h (4)	100	100	2x100	50	50	50	100 (2)
< 200 m^3/h	100	100	***500***	50	50	50	100 (2)
< 250 m^3/h (4)	100	100	2x100	50	50	50	100 (2)
< 250 m^3/h	100	100	***500***	50	50	50	100 (2)
< 300 m^3/h	200	200	***500***	50	50	50	100 (2)
< 350 m^3/h	200	200	***500***	100	100	100	100 (2)
< 400 m^3/h	200	200	***500***	100	100	100	100 (2)
< 500 m^3/h	***500***	***500***	***500***	100	100	100	100 (5)
< 600 m^3/h	***500***	***500***	***500***	100	100	100	100 (5)
< 700 m^3/h	***500***	***500***	***2x500***	200	200	100	100 (5)

(1) Assuming and adjustment of 1 point in pH range with nitric acid at 40%

(2) Assuming an adjustment of 2 points on pH range with nitric acid at 40%

(3) Assuming and adjustment of 2 points in pH range with nitric acid at 60%

(4) Exclusively using a Multifertic® pump and two heads injecting K at the same time.

(5) The flow rates inside a frame refer to Electrofertic 2000® models, all the others refer to heads of the Multifertic® dosing pump.

6. AUTOMATED CONTROL OF FERTIGATION

The main purpose of fertigation in golf courses is to improve the performance and regularity of fertilization and a reduction of the purchase and application costs of fertilizers by controlling the irrigation solution.

Controlling the application of fertilizing products allows to improve the concentrations and relationships between nutrients, contributing balanced solutions. It also allows to establish a given pH level which will increase the system efficiency, improving the absorption of nutrients and preventing the precipitation of fertilizers or of dissolved salts in the irrigation water, and helping to maintain the irrigation systems.

The automation of the fertilization control ensures a total uniformity in this operation, since the chemical features (products proportion, acidity) will not be modified by the flow differences in the different irrigation areas, or by those caused by the water variations.

It can also improve the system security by establishing alarms which, if properly handled, can stop the irrigation, the fertilization, or give a visual, acoustic, etc. warning.

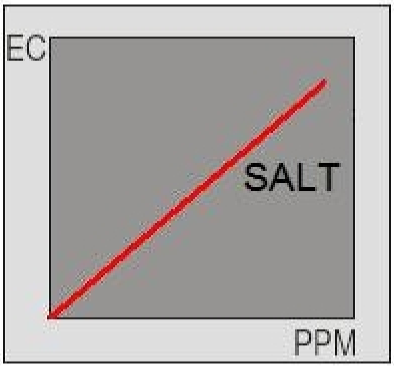
Below are detailed some of the systems developed by ITC for the knowledge and control of dosage and its optimization under different conditions which may be found in golf courses.

6.1. Basic control elements in fertigation

6.1.1. Proportionality

It is the relationship between the amount of a product dissolved in the irrigation water and the volume of water containing it. If we know the flow of an irrigation network and the concentration of a main fertilizing solution, we may establish the flow necessary to reach a given proportion.

6.1.2. Conductivity



It is the ability of a solution to transmit the electric current. (mS/cm).

The main factors which bear upon this conductivity reading are: applied voltage, viscosity of the medium, temperature and the type and number of charges in the solution (concentration and nature of fertilizers).

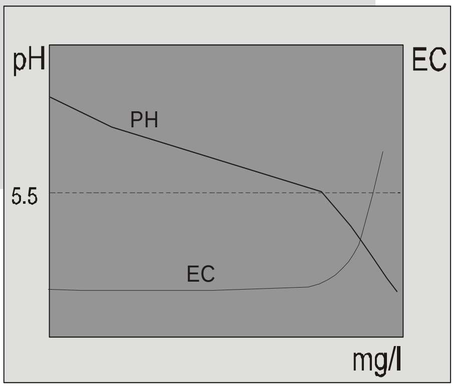
Therefore the conductivity reading is in proportion to the amount of salts dissolved and it is possible to obtain an exact reading in ppm.

This reading may be disturbed with low pH levels, which may increase it and impair its correlation with the fertilizers.

6.1.3. Acidity (pH)

The pH value, between 1 and 14, indicates the acidity degree of a dissolution. The lower the value the greater the solution acidity.

$$pH = -\log [H^+]$$



The main factors which bear upon the pH reading are the type and number of charges in the dissolution (concentration of acid or alkaline substances), which depend on the products dissolved and their reaction.

The introduction of acid must be done exactly, since the behaviour of the pH values is not proportional to the acid concentration.

6.2. Reading physical and chemical values of the irrigation solution: LECTOR®

Knowing some basic variables (Acidity or pH level, Irrigation flow and Conductivity) allows to optimize the nutrients dosage in the irrigation network.

LECTOR ® offers us a constant visualization of the instant irrigation flow, the conductivity and solution pH. It allows to establish maximum and minimum alarms for each one of the variables.

The reading is done by connecting it to the pH, conductivity and flowmeter probes.

PH PROBE

Constant measuring of the pH value of the solution which circulates in the irrigation piping.

CONDUCTIVITY PROBE

With automatic compensation of temperature.

FLOWMETER

Insertion flowmeter. Continuous measurement of the instant flow in piping.

6.3. Control equipments by means of a SERVOMOTOR

Pump with one of its modules
regulated by a servomotor

The servomotor adjusts its piston stroke or the deformation of a diaphragm to a given percentage according to the orders given by a controller:

- **CONTROLLER 2000 CP®,**
- **CONTROLLER 2000 CS®,**
- **CONTROLLER 2000 SERVOS ®**

COMPACT-S ® is a controller which adjusts the piston stroke or the deformation of a diaphragm, by means of its own SERVOMOTOR, to a percentage of its nominal flow in order to establish a pH or a Conductivity value.

It also allows to dose in proportion to the irrigation flow measured instantly by means of a flowmeter.

It also allows to dose in proportion to the irrigation flow measured instantly by means of a flowmeter:

- Instant flow (m3/h or GPM)
- Conductivity
- pH

It allows to establish max/min alarms for all the visualized values. It has a direct connection to pH, Conductivity and Flowmeter probes.

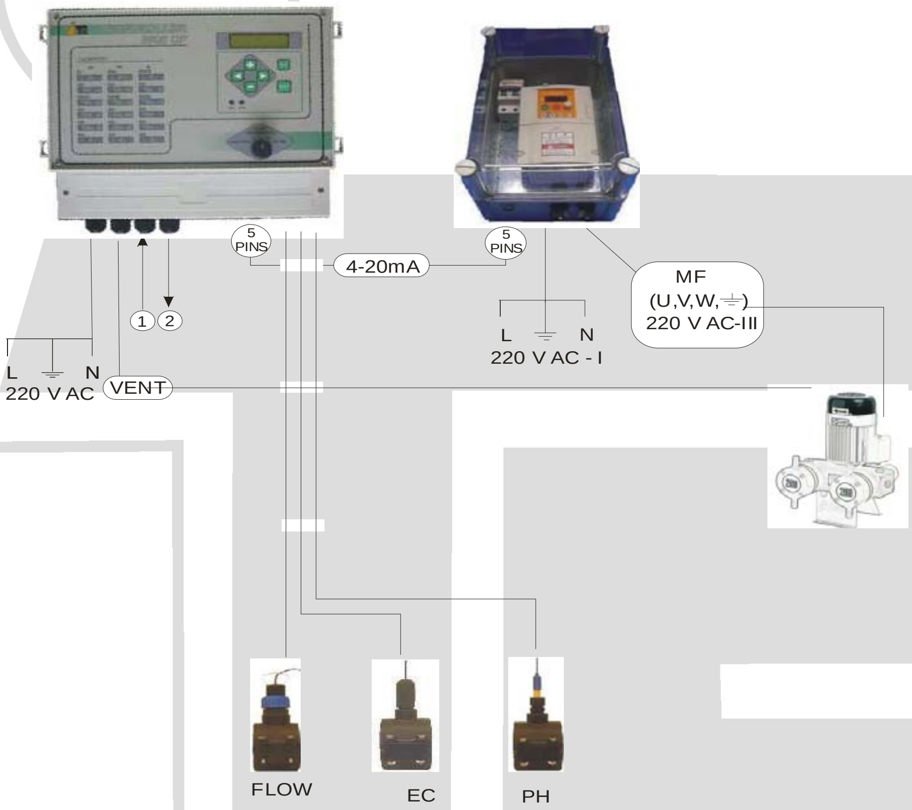
*Pump with one of its modules adjusted through **COMPACT-S®***

6.4. Control equipment by means of a FREQUENCY INVERTER:

COMPACT-V CP ®

When the motor of a dosing pump works at a frequency of 50Hz, each head injects a flow equivalent to the nominal flow, modified according to a reduction fixed in its piston stroke.

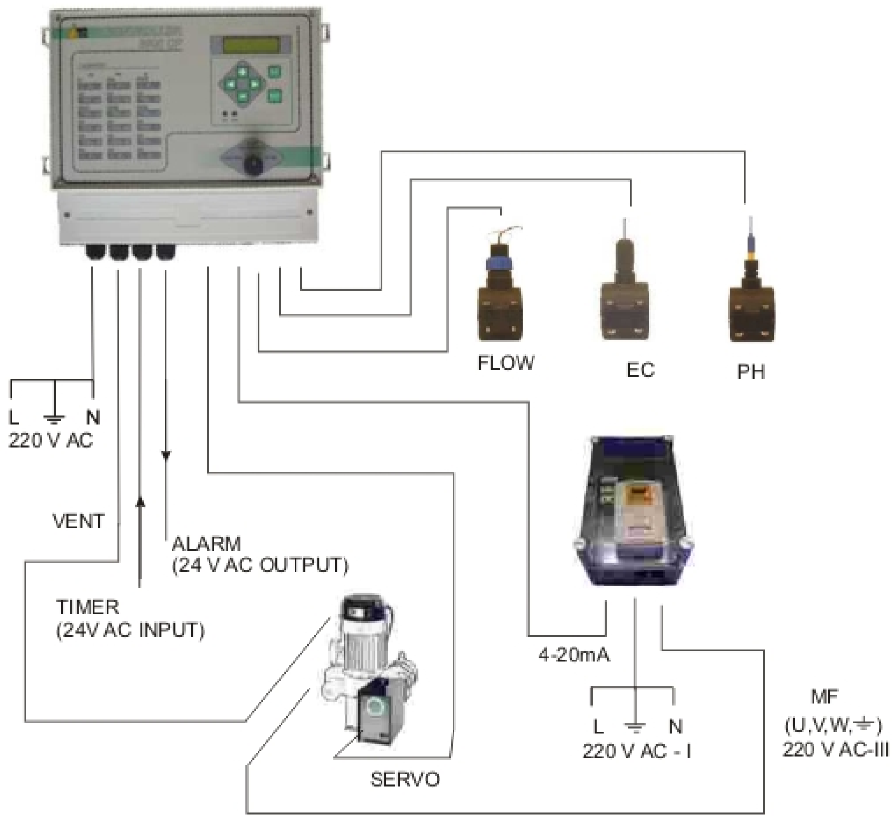
We may regulate the motor speed by increasing or reducing the electric frequency by means of a FREQUENCY INVERTER. In this way we control the injections frequency, and it is possible to inject from 10% to 120% of the established flow in all the heads of a dosing pump. The output above the nominal flow may be reached by feeding the motor a power of frequency higher than 50Hz. So if for example we feed 60 Hz to a pump of Qn = 100 L/h, we obtain an effective flow of 120 L/h.



The **COMPACT-V CP ®** controller allows to regulate, through a 4-20 mA signal, the feeding frequency of the dosing pump by means of a frequency variator. This control affects simultaneously all the heads working in the same dosing pump, and all the pumps fed through the same variator.
It is possible to inject proportionally to the irrigation network flow, or to adjust the injection frequency in order to establish pH or Conductivity values. It offers a constant visualization of the instant Flow, Conductivity and pH. It allows to establish max/min alarms for each one of the values.

6.5. Control equipment by means of a FREQUENCY INVERTER and a SERVOMOTOR: CONTROLLER 2000 CP®

It is possible to adjust the motor speed by means of a FREQUENCY INVERTER and at the same time to adjust the stroke of one of the pistons by means of the SERVOMOTOR. We may establish this control with the fertigation CONTROLLER 2000 CP®.



The **CONTROLLER 2000 CP®** allows the dosage of products according to a predetermined proportion and the constant reading of flow by means of an insertion flowmeter, and at the same time it can adjust the acid injection to a given pH level established by the user. The fertilizers injection is usually dosed through the FREQUENCY INVERTER, and the acid injection by means of the SERVOMOTOR.

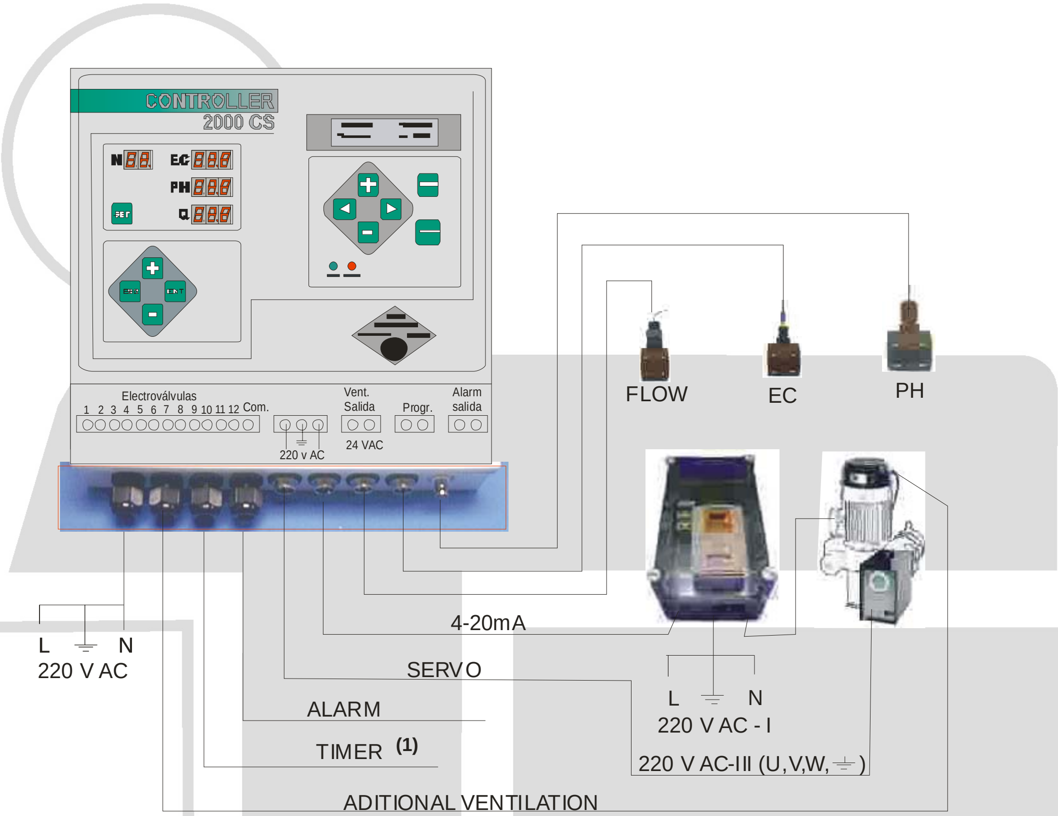
The CONTROLLER CP® alternately allows the dosage by means of conductivity values for the injection of fertilizers.

It is possible to establish max/min alarms for all the values: Flow, Conductivity and pH.

6.6. Fixing different setups for fertigation: CONTROLLER 2000 CS ®

CONTROLLER 2000 CS ® allows to establish different setups of Proportionality, Conductivity or Acidity following a signal of fertigation 24VAC, and fixing or avoiding different alarms for each of the fertigation areas.

This feature allows to apply different concentrations of fertilizers with the same multihead dosing pump, according to the fertilizing strategy, cultivated species or varieties, state of development, and specific substratum features.



The **CONTROLLER 2000 CS ®** can be coupled to any irrigation programmer with a signal for electrovalves 24 VAC or 12 VCC, and up to 12 different fertigation setups can be established.

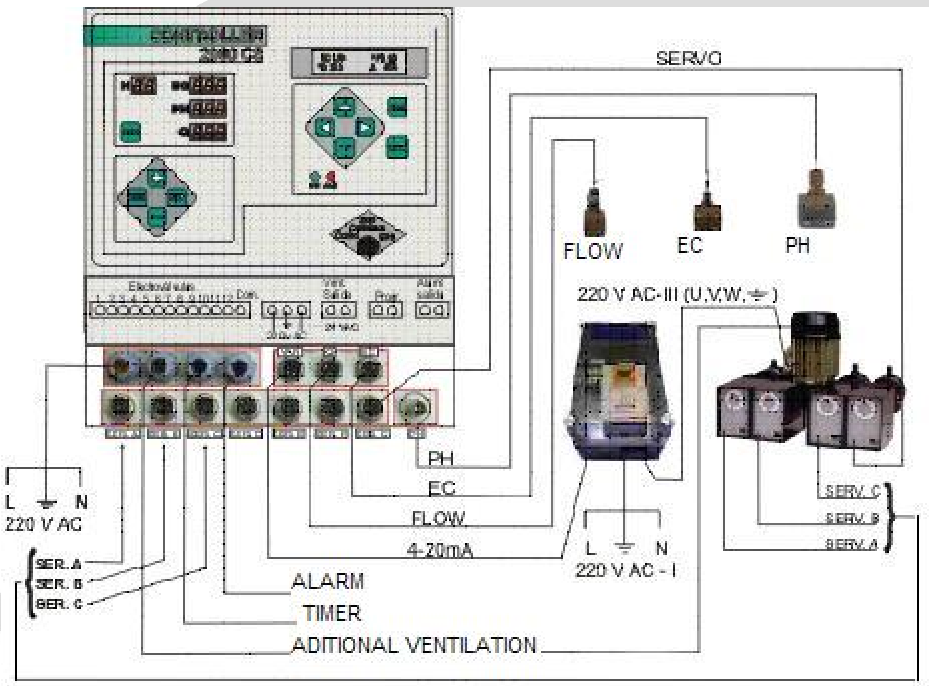
As for the previous controllers, it offers a constant visualization of flow, conductivity and pH instant values, informing us besides of the activated fertigation area.

6.7. Fixing different fertigation formulae: CONTROLLER 2000 CS SERVOS ®

The **CONTROLLER 2000 CS SERVOS ®** allows to establish not only different setups of proportionality, conductivity and pH depending on the irrigation area working, but also different formulations in the proportion of the different fertilizers themselves.

The regulation of the fertilizers proportion is carried out by using a servomotor for each head.

The automatic regulation of the injection flow of fertilizers in accordance with instant irrigation flow (proportionality) or in accordance with the instant conductivity value is carried out through the use of a Frequency Variator, which regulates the motor revolution speed.

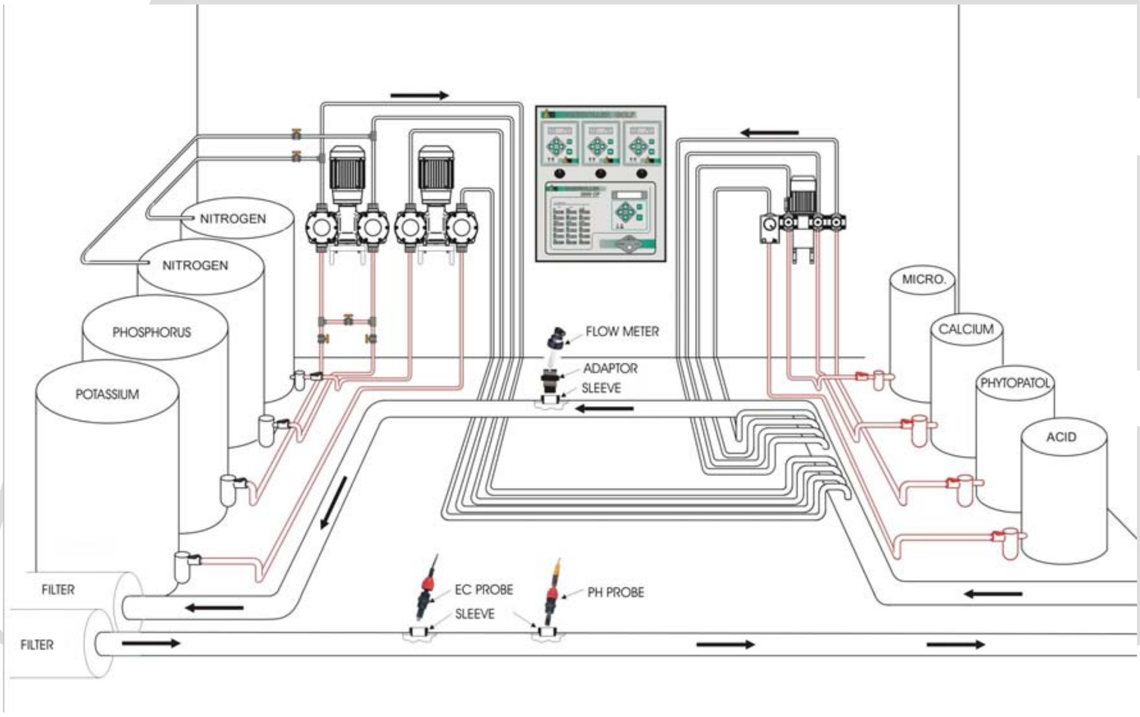


The injection of acid can be fixed in accordance with the instant pH value of the irrigation network, activating the servomotor of one of the heads. This automatic regulation is carried out simultaneously to the injection control of fertilizers by means of the frequency variator.

6.8. A specific formula for large flows in golf courses: CONTROLLER GOLF 2000 CP ®

The high requirement needed for maintaining golf courses, together with the high flows often needed because of the irrigation time limitations, make it necessary to use high flow and pressure dosing pumps, whose automation through a SERVOMOTOR has not been yet developed. These high performance dosing pumps, such as the ELECTROFERTIC 2000®, may be used for the injection of those elements which must be applied in larger flows, such as N, P and above all K, while the MULTIFERTIC module will be suitable for the injection of products needed in smaller quantities, such as microelements, deficiency correctors, phytopathological products, sodium contents correctors, and an acid for controlling pH.

The **CONTROLLER GOLF 2000 CP®** allows a proportional and independent dosage according to setup for each of the chosen macronutrients, besides the proportionality for one of the remaining additives with hand- adjustment in each head.



At the same time the pH control will be carried out in accordance with an setup fixed in advance by the caretaker by regulating the piston or diaphragm stroke, controlled by a SERVOMOTOR in the MULTIFERTIC® pump.

7.1. pH Control

The pH control in the irrigation water is in itself an important improvement in the nutritional operation of a golf course. The improvement of the water quality in this case allows a greater availability of nutrients for the crop and a lower occurrence of interruptions, mainly those related to phosphorus and iron.

An effective control of pH can be carried out by means of an acid injection. The acids most used are nitric (HNO_3), phosphoric (H_3PO_4) and sulphuric (H_2SO_4), which may be dissolved at any concentration in the main solution. The head choice must take into account both the acid to be used and its concentration, such as the maximum flow to be treated and the points to be adjusted in the scale. In the enclosure at the end of this document there are tables which allow the forecast of maximum and minimum quantities for an adjustment of 1 or 2 points in the pH scale for acids detailed in different concentrations.

It is also possible to establish in a more realistic way the acid consumption by evaluating the necessary acid amount. The calculation may be done by adding amounts of the acid solution to be used in a 5 liter container of the water to be used, while constantly stirring, until the pH reading reaches the desired value. The minimum flow of the head will be:

$$Q_N = \frac{Q_R \times V \times 1{,}1}{500}$$

... where:

	Q_N	Nominal flow of acid injection head (in L/h)
	Q_R	Maximum instant flow of irrigation (in m^3/h)
	V	Volume in ml of required acid calculated for 5 L water

The ITC dosing pumps collars are made in Viton, which is a material resistant to acids. We can also use diaphragm heads, absolutely watertight and having their surface in contact with the Teflon product. Should we work with exothermal products, such as sulphuric acid, it may be advisable to choose an stainless steel module. Should we work with piston, choosing a ceramic module will ensure a long life thanks to its stability and resistance in extreme working conditions.

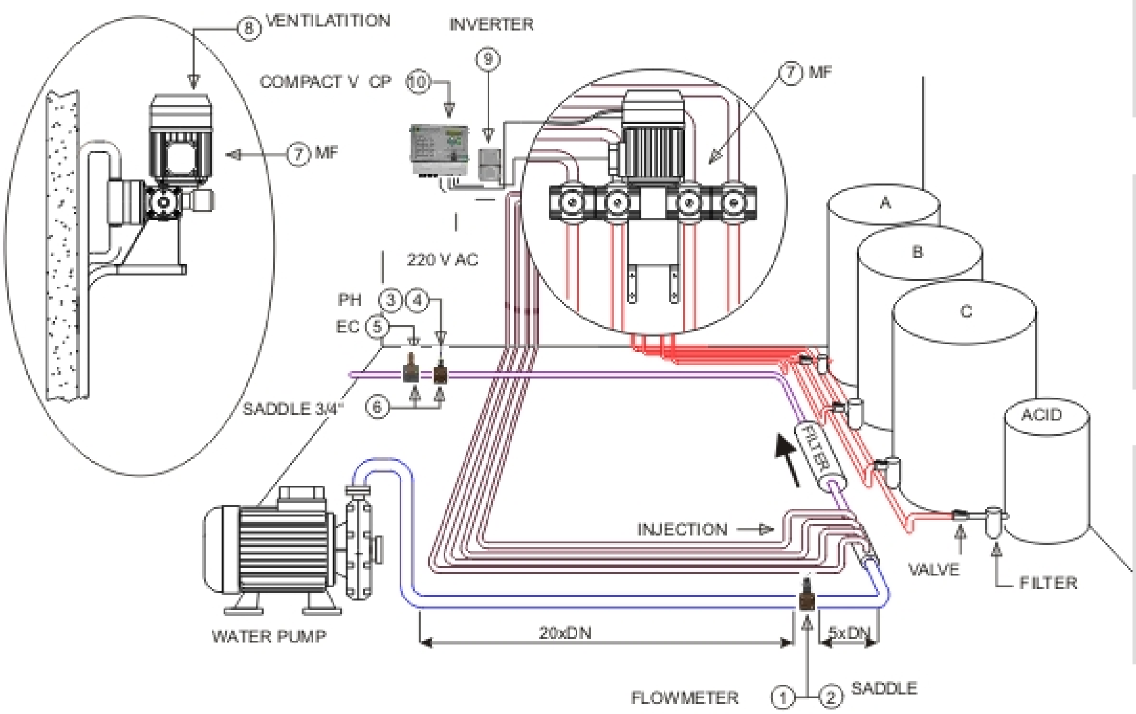
pH control can be carried out by being aware of it through the use of a probe, and correcting it by increasing or reducing the acid injection, either working on the injections frequency of acid, or working on the amount of acid in each one of them (systems with servomotor). These processes can be carried out in an automated way by means of COMPACT-V® (through an inverter) or COMPACT-S® (through a servomotor). These controllers permanently adjust the injection feature correcting the pH instant reading to attain the setup fixed in advance by the user.

7.1.1. Correction of pH by means of COMPACT-V®

The equipment to correct acidity by means of establishing the pH through the Compact-V® is made up of:

- Electric dosing pump Multifertic®
- Frequency inverter for Multifertic® pump
- pH probe
- COMPACT-V® controller
- Acid tank (with agitator if we want to inject soluble products; without agitator for acid originally liquid)

The dosing pump can be started following an exterior signal 24VAC received by the COMPACT-V® Controller, or either by spotting the flow in the irrigation piping, for which it will be necessary to have a flowmeter or a flow detector. It must be pointed out that in case of low flows on the limit of the flowmeter ability (it may be a minimum speed of 0.3 m/s) there will be no pH adjustment



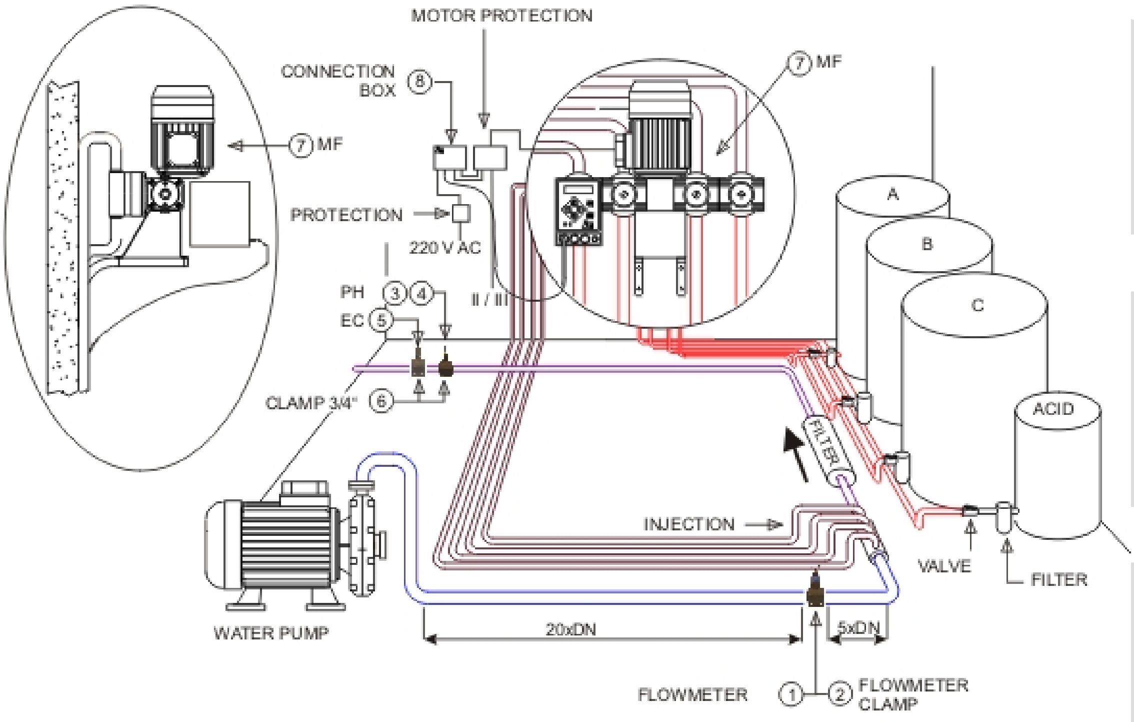
Installation diagram of a COMPACT-V® equipment

7.1.2. pH correction through a COMPACT-S®

The equipment to control acidity by means of a pH setup through the Compact-S® is made up as follows:

- Multifertic® electric dosing pump
- pH probe
- COMPACT-S® controller (with its own SERVOMOTOR)
- Acid tank (with agitator if soluble products are to be injected; without agitator for acids which are originally liquid)

The work process of Compact-V® is quicker than that of Compact-S®, as it does not require the displacement of any mechanic element, and the reaction to the order of change in the injection features is immediate. This makes the Compact-V® more suitable for the treatment of large and very variable flows. However, Compact-S® offers a greater uniformity in the pH control in low, little variable, flows, since it holds a high injection frequency.



Installation diagram of a Compact-S® for acidity control

7.2. Fertigation without pH control

The fertilizer dosage in each of the programmed irrigations allows a continuous watering, avoiding the rushes and falls which are peculiar to discontinuous fertilizations. Therefore it is clear that the best option is to fertilize in each irrigation operation, supplying the crop with all the necessary nutrients for a given period (weekly, monthly…) constantly dissolved in the irrigations programmed for that period. We offer an approach to the calculation of the fertilizers concentration according to this system in chapter: “Calculation of fertigation in one given period”.

On the other hand, a discontinuous fertilization, very especially in large fields or in those in which the water volume contained in the pipes is important, implies errors for an excess or a default of fertilization caused by the filling and emptying of the piping, an error which is corrected when we fertilize in a permanent way.

As with the pH control systems, we find very different flows for treatment. The best option appears to be the permanent proportional fertilization. The equipment to carry out this fertilization in fields with irrigation flows of up to 250 m3 may be a Multifertic® pump with different heads injecting different products which are incompatible in the main solution concentration. Higher flows may be handled with two Multifertic® working together fed by a frequency inverter according to the signal 4/20 coming from a controller, and even by using ELECTROFERTIC® dosing pumps independently controlled following a proportionality setup given by COMPACT-V®.

In any case, the best solution will depend also on the pressure in the injection point, as it can be observed in the tables contained in chapter “Sizing of dosing machines”.

On page 41 there is more information on the COMPACT-V® equipment, which may be used to control the fertilizers injection, correcting and phytopathological products through one or more MULTIFERTIC® dosing pumps with several injection heads, or through an ELECTROFERTIC 2000® dosing pump.

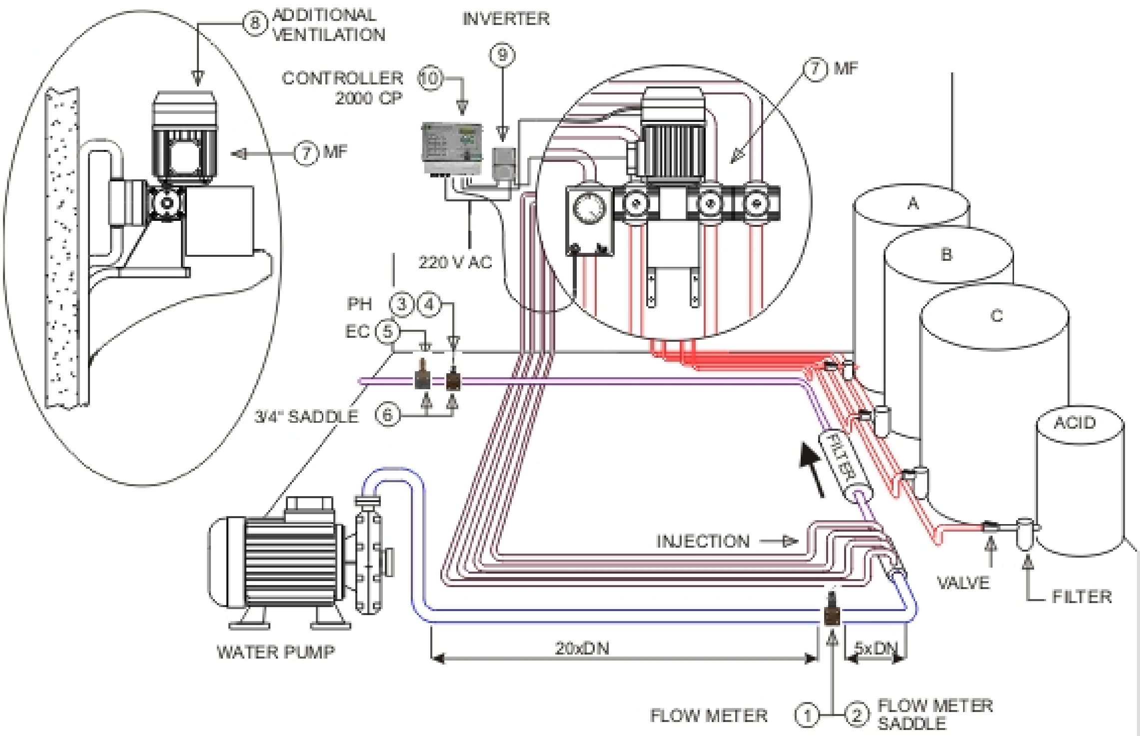
7.3. Fertilization with simultaneous control of pH

To obtain the best nutrition results it is necessary to control not only fertilizers but also simultaneously pH.

This allows the nutrients to reach the plant in a usable way, avoiding the economic and effectivity loss implied in standstills, precipitation or transformation into forms not usable by the vegetals of those products which we have injected in the network. This loss may be especially important in golf courses, because of the high volume of solution which may remain in the primary and secondary networks and the time they stay there.

The proportional fertilization and simultaneous control of pH may be carried out through one or more MULTIFERTIC® dosing pumps with CONTROLLER 2000

CP®, acting on the fertilization in accordance with a proportionality setup, and on the acid injection in accordance with an setup for pH.



Installation diagram of fertigation by a CONTROLLER 2000 CP® acting on a MULTIFERTIC® pump for the injection of 3 different products and a simultaneous pH control.

The simultaneous dosing and pH control for large flows, and especially for those in which the use of the ELECTROFERTIC 2000® pump is required, may be carried out through the CONTROLLER GOLF 2000 CP®. This controller besides offers the possibility of carrying out a discontinuous fertilization according to a fertigation signal “Timer” at the same time as the supply of salinity correcting products, phytoregulators and pH is controlled permanently and independently from fertilization.

On page 39 there an installation diagram of CONTROLLER GOLF 2000 CP®.

7.4. Strategies for a differentiated fertilization

The differences in the cultivation requirements of the various areas in the same golf course require the adoption of a strategy which will allow us to cover the minimum requirements of the sensitive areas, usually greens and antegreens, without subjecting the tees, fairways and roughs to an uneconomical and inappropriate overfertilization.

We may separate fertilization in quantity and quality if we have an independent irrigation network for each area to be treated. However, in many courses the irrigation area has been foreseen only as a water distribution. Since there is no separation we shall have to apply different strategies.

With respect to quantity these differences may be treated by programming enough irrigations in the most demanding areas to supply the fertilizing units requested. Keeping in mind that the greens cover a minimum portion of the total surface to be irrigated, and that they already receive a larger amount of water (L/m2) than the remaining areas, the increase in the amount of water supplied with irrigation is very low.

To explain this procedure, we may take the example of chapter “Calculation of fertigation in one given period”. Let us imagine the following requirement of fertilization and irrigation foreseen in one month:

	Greens	Remaining field
Kg/Ha N	45	25
Kg/Ha P_2O_5	18	10
Kg/Ha K_2O	27	15
L/m^2 irrigation (or mm)	150	100
Surface	12.000 m^2	388.000 m^2
Water consumption	1.800 m^3	38.800 m^3

As we said in our previous calculation, we shall inject:

18 L/h N-32
21 L/h NH4H2PO4 at 20%
33 L/h Potash Acid Solution at 15%

With this we shall obtain the right concentration for the remaining field. However, it is possible that this concentration is not right for the greens. We may easily find out with the concentration of the nutrient which is proportionally more needed in the greens than in the remaining field. In our example, all of them keep the same balance.

In the case under consideration, the greens' irrigation adjusted to the foreseen water needs would offer to the cultivation:

$$150\ L/m2\ irrigation = \frac{25\ Kg/Ha\ N}{100\ L/m2\ irrigation} = 37{,}5\ Kg/Ha\ N$$

This is below the established needs. We shall therefore increase the irrigation to reach the requested fertilization level:

$$450\ Kg/Ha\ N = \frac{100\ L/m2\ irrigation}{25\ Kg/Ha\ N} = 180\ L/m2\ irrigation\ in\ green$$

In practice this will mean an increase in the frequency or in the irrigation quantity in each operation. The extra amount of water used to irrigate the greens in our example will be:

$$30\ L/m^2 \times 12.000\ m^2 = 360\ m^3$$

...which shows a consumption increase during this period of0,9% on the total.

Should the water consumption difference be higher than the fertilizer consumption difference, of course there will be no cost increase.

In order to simplify calculations we have not introduced this parameter, but the exact calculation of fertigation for each area can be effected taking the pluviometry and multiplying it by the concentration of the irrigation water nutrients.

In the previous example, besides, we have kept in mind that the balance between the different areas is the same. Should we need different formulae for the different field areas, and there is not a differentiated distribution network, the fertigation shall be upgraded with a surface fertilization which will round off the specific needs of these areas.

Another possible strategy for differentiation will be to establish a periodical irrigation cycle, let us say on a weekly basis, in which the irrigation concentration and/or balance will vary. To this end we shall have to foresee this cycle and "fill" the piping with the new formula already in the previous irrigation cycle. To this end it will be necessary to calculate the necessary time to previously substitute the solution, in accordance with the capacity of the primary piping and the irrigation flow. A tentative calculation could give us an idea, dividing the piping capacity by the irrigation flow. For example:

$$\frac{250\ m3\ primary\ piping\ capacity}{470\ m3/h\ irrigation\ flow} = 0{,}53\ h$$

$$0{,}53\ h \times 60\ min/h = 32\ min$$

Or, said in a different way, we should start the injection of the new fertigation formula during at least 32 minutes irrigation before the greens' irrigation. This would be right for a lineal installation where we would take advantage of the irrigation of the farthest injection point area to fill the piping. However, it will be necessary to carefully consider the field topology and the distribution network. This system may cause a slight error for an excess fertilization in some areas which are irrigated during the solution change. Of course this system will be more effective if it is applied in the farthest areas, as on the contrary case it will happen that the areas of the remaining field will absorb the new solution.

The adoption of this strategy will be based on a careful study of the piping layout improving the order in which the areas of the remaining field and of the greens are activated, if the irrigation programmer allows it.

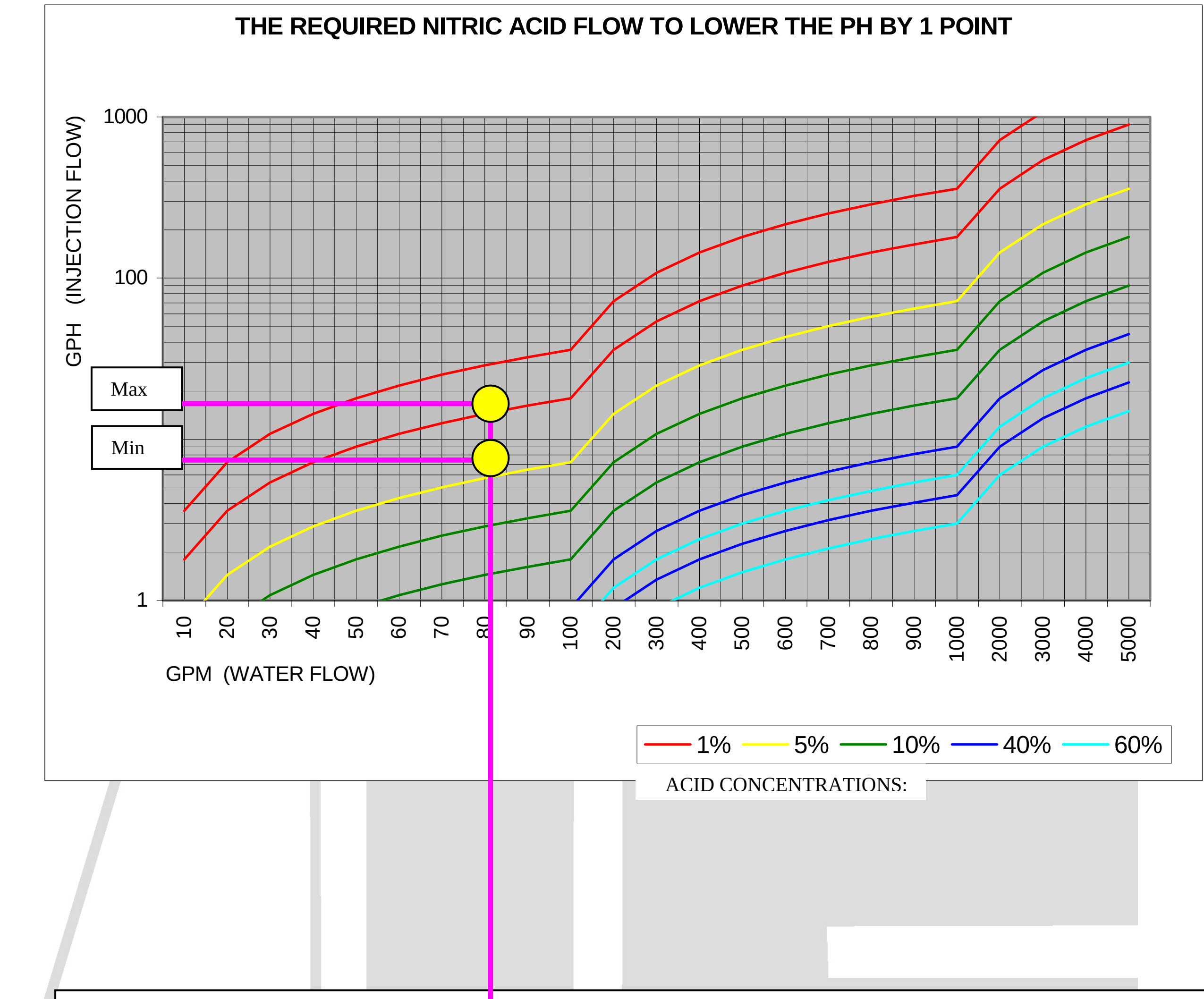
The automation of these changes in fields fertigated with MULTIFERTIC pumps can be carried out by means of the following controllers:

CONTROLLER 2000 CS®: it allows to fix up to 12 different setups depending on the signal 24 VAC sent by an irrigation programmer.

CONTROLLER 2000 SERVOS®: it allows to fix up to 12 different setups and formulas of fertigation depending on the 24 VAC signal sent by an irrigation programmer.

Establishing different setups when the control is carried out through CONTROLLER GOLF 2000 CP® may be automated with the setup administrator SECTOR GOLF.

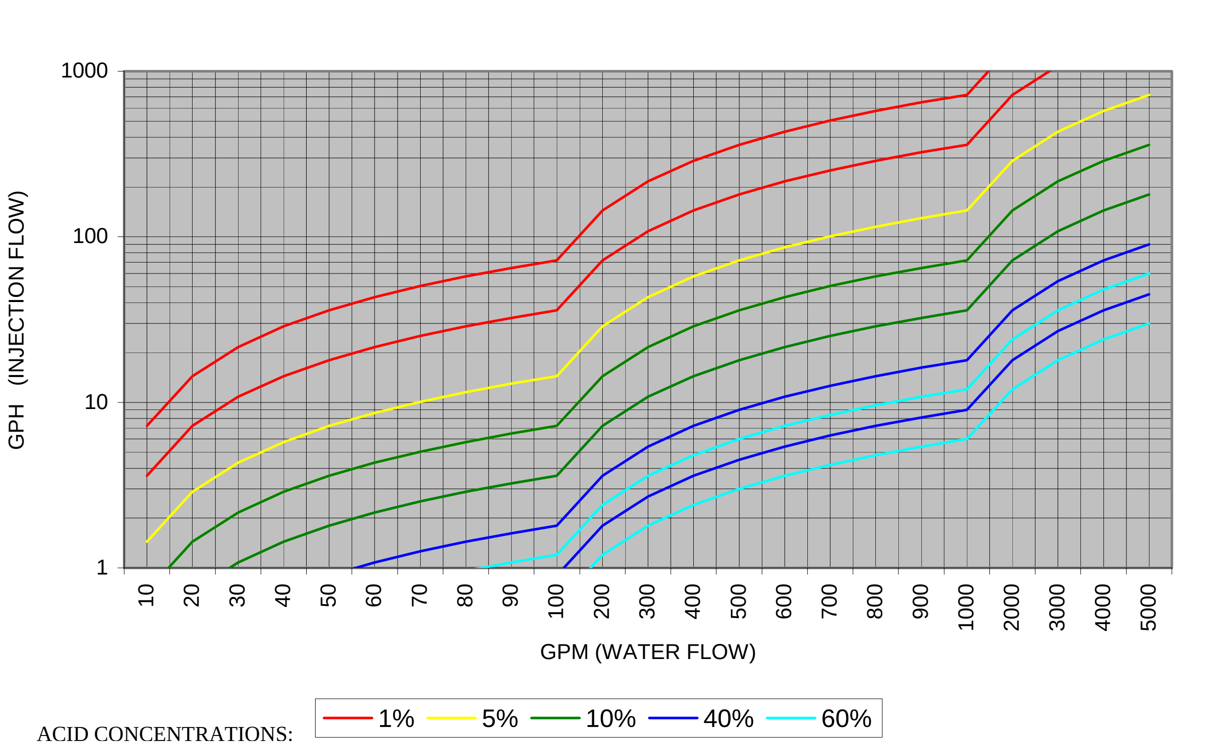
INJECTION HEAD NEEDED



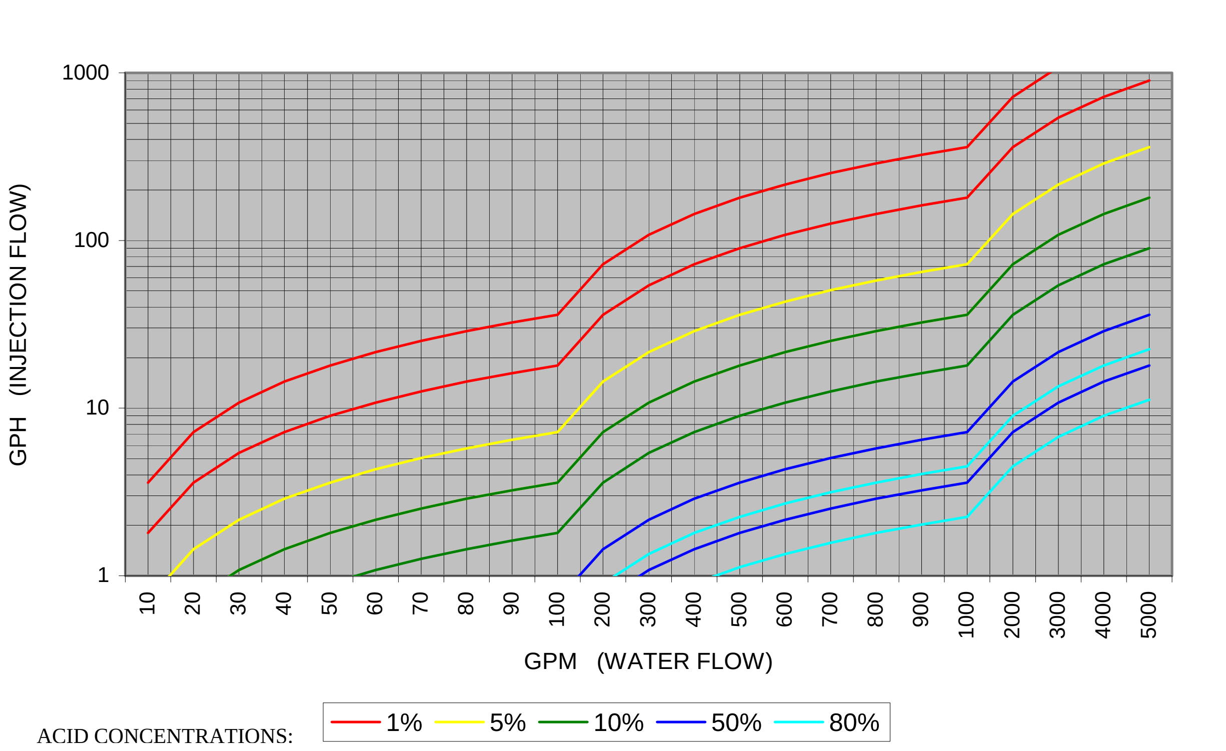
Example:
A water flow of some 80 GPM with an acid concentration of 1% (Red curve), means an Injection Head to cover the range of 15 to 30 GPH is necessary.
In this case an Injection Module (MI2-100) is choosen. Keep in mind that at 50 Hz an injection flow of 26 GPH is obtained and at 60 Hz an injection flow of 32 GPH

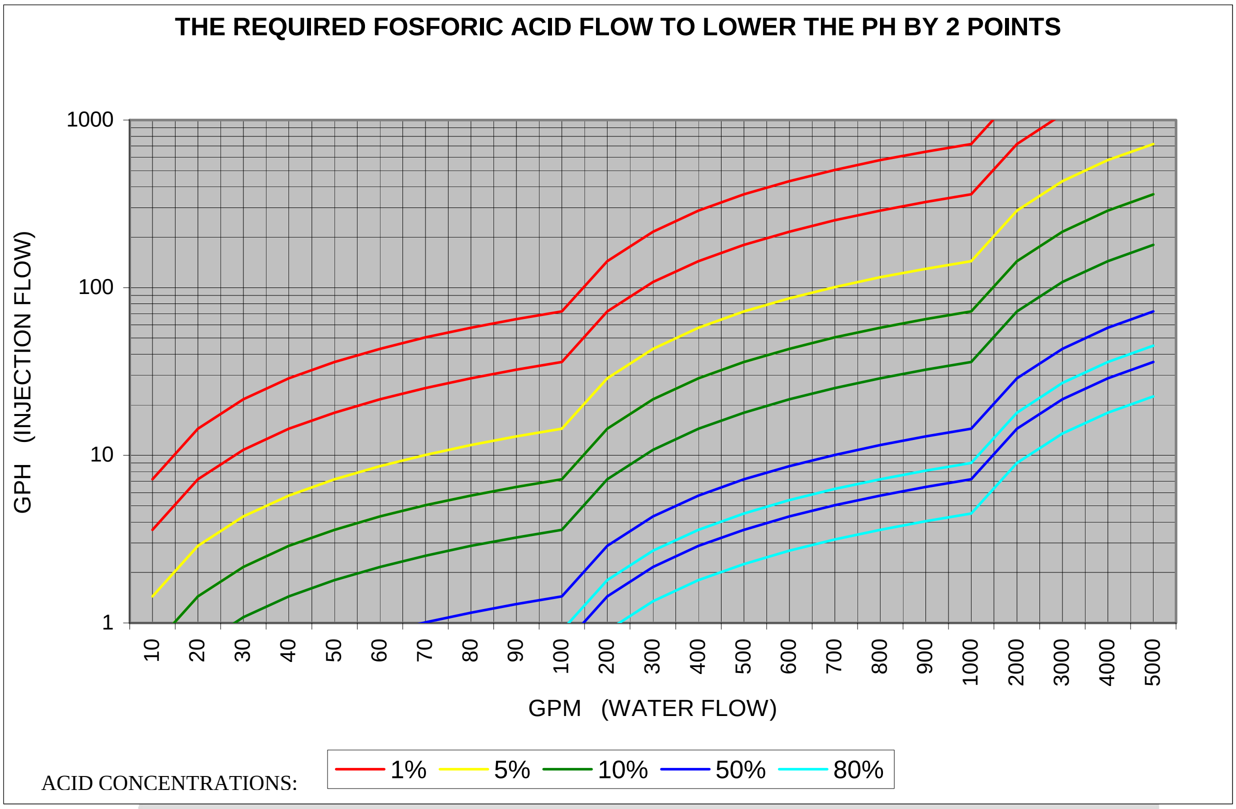
The curve for the minimum acid flow 5% coinsides with the curve for the maximum acid flow 10%.

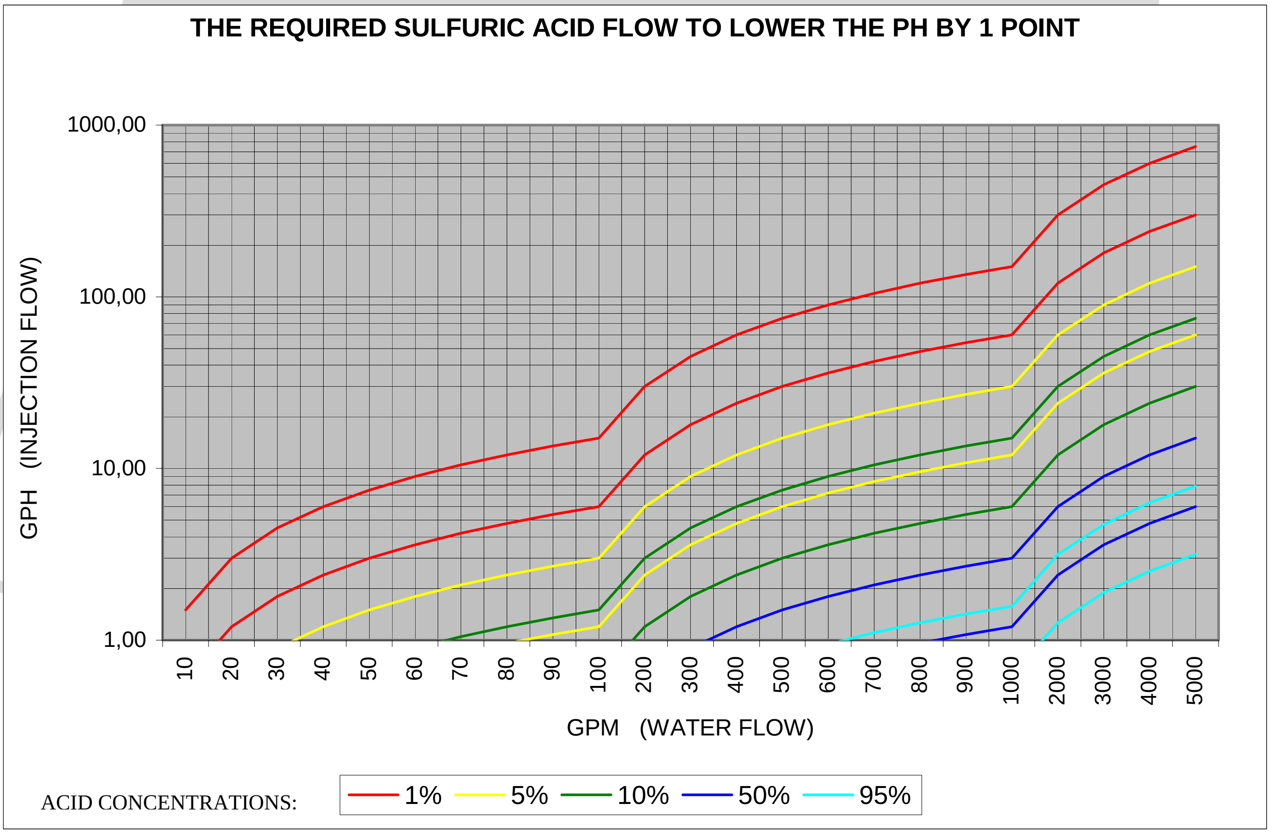
THE REQUIRED NITRIC ACID FLOW TO LOWER THE PH BY 2 POINTS

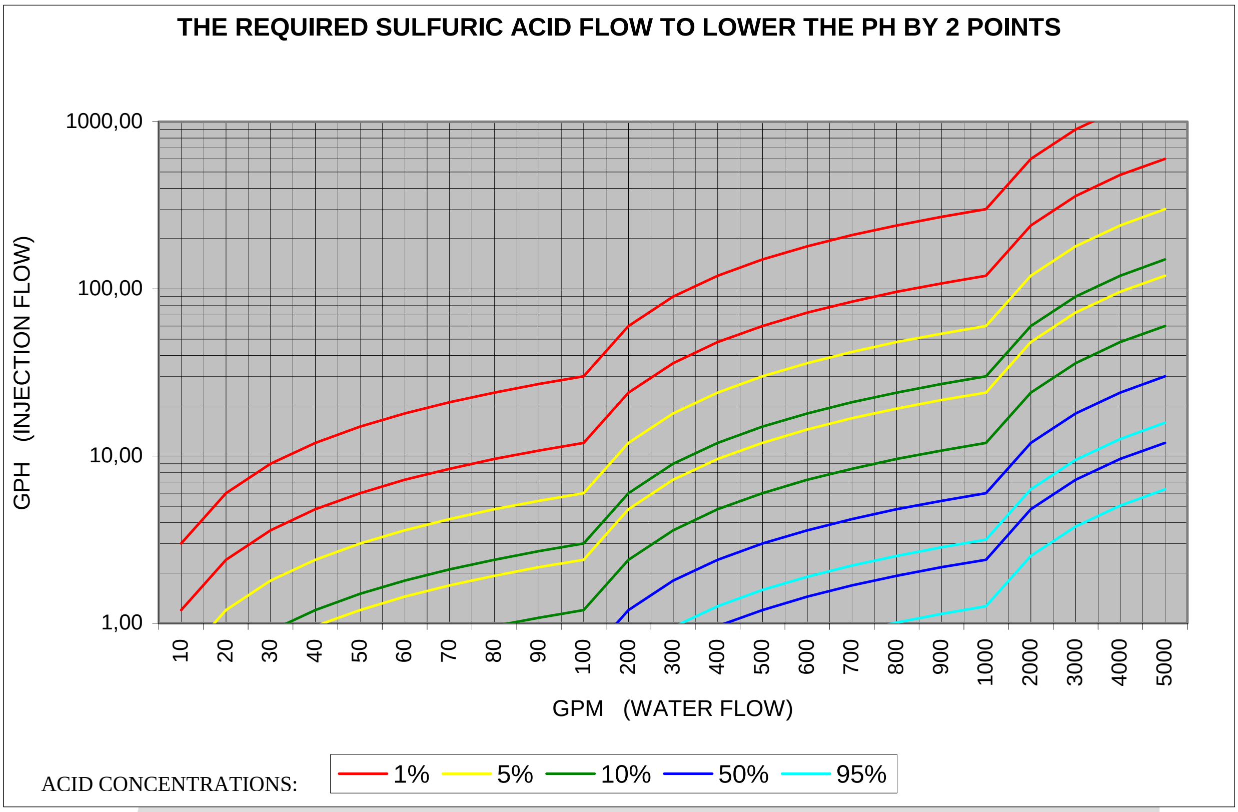


THE REQUIRED FOSFORIC ACID FLOW TO LOWER THE PH BY 1 POINT




THE REQUIRED FOSFORIC ACID FLOW TO LOWER THE PH BY 2 POINTS
GPH (INJECTION FLOW)
1000
100
10
1
10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000 2000 3000 4000 5000
GPM (WATER FLOW)
ACID CONCENTRATIONS:
1% 5% 10% 50% 80%


THE REQUIRED SULFURIC ACID FLOW TO LOWER THE PH BY 1 POINT
GPH (INJECTION FLOW)
1000,00
100,00
10,00
1,00
10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000 2000 3000 4000 5000
GPM (WATER FLOW)
ACID CONCENTRATIONS:
1% 5% 10% 50% 95%


THE REQUIRED SULFURIC ACID FLOW TO LOWER THE PH BY 2 POINTS
1000,00
100,00
10,00
1,00
GPH (INJECTION FLOW)
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
GPM (WATER FLOW)
ACID CONCENTRATIONS:
1%
5%
10%
50%
95%

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