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USE OF IRRIGATION EQUIPMENT FOR AGRICULTURAL PROJECTS AND POSSIBILITIES OF LOCAL MANUFACTURING IN DEVELOPING COUNTRIES *

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I. INFLUENCE OF LOCAL CONDITIONS ON THE SELECTION OF APPROPRIATE IRRIGATION TECHNOLOGY

General introduction

1. Agricultural production must increase worldwide not only in order to maintain but also to improve the nutritional level of an ever-expanding population. Production bottlenecks must be reduced and prevented. The incidence and availability of water is certainly the most important contributing factor to production bottlenecks in arid and semi-arid parts of the world. By ensuring that fields receive a better water supply, the crop yield per hectare could be increased many times over and a guaranteed harvest could be achieved.

The influence of appropriate irrigation on the ecological soil system

2. The ecological system is usually defined as an interaction of organisms and factors which make up a common environment. The ecological system is constantly subject to changes brought about by elementary factors such as light and heat and also by complex factors such as climate etc.

3. When assessing the influence of irrigation on the ecological soil system it is essential to observe the conditions causing these changes. In particular, climatic changes play an important part in the development of the ecological systems in plant, animal and human spheres: an important example of this is the climatic changes and related ecological changes in the Sahelian region where, between 1968 and 1984, drought created a disastrous situation for the plant and animal world and consequently for the local population.

4. Irrespective of whether these changes were caused by the shift in the tropical monsoon zone towards the equator or by direct human intervention, the fact remains that the Sahara Desert is expanding southwards at a rate of 50 Km per year.[1/]

5. Irrigation creates a complex water economy scheme consisting of wells, reservoirs, water-supply canals, overflow and drainage ditches which ensure that water is distributed accurately to predetermined areas. It is, therefore, indisputable that irrigation exerts a tremendous influence upon the preservation and also upon the development of new ecological systems. After the introduction of irrigation schemes in soil which, up till that time, had been insufficiently supplied with water, the existing soil systems undergo tremendous dynamic changes: in many cases these systems cease to exist and a new ecological system emerges.

6. Irrigation causes a moisture ratio to develop in the soil which encourages a favourable metabolism, an increase in microflora and the emergence of fauna in the soil. The existence of microflora in soil exerts an extremely positive influence on the ecological system of cultivated plants. Mould, bacteria and other micro-organisms are influenced in that the number of individual organisms rises while the actual number of species decreases. Animal life in the soil is also greatly influenced. Fauna is sparse in arid soil and it is specially adapted to aridity. Irrigation usually causes the destruction of previous ecological systems and the creation of new ones whose main feature is the presence of earthworms, mites and nematodes. Earthworms, of course, play an extremely important part in the formation of topsoil. Their presence serves to loosen and aerate soil simultaneously.

7. Increased evaporation and transpiration cause considerable changes to take place in the microclimate. The moisture level rises and the temperature decreases, thereby causing a reduction in transpiration. Increased moisture in soil assists the oxidation process, cools the surface of the soil and slows down the mineralisation of organic substances in the soil; this has a favorable effect on the increase in humus concentration, particularly in arid soil.[1/]

8. The water balance of the ecological system of plants is defined by the intake and supply of water and its function. The most important functions of water in connection with the eco-systems of cultivated plants are as follows:

- Water serves as a means of dissolving and conveying plant nutrients which can only be absorbed by the plants in solution.
- Water is a major constituent of plant cells. It is absorbed into the cells by means of osmotic and suction forces. It greatly influences the physical structure of the plants.
- Water plays an important role in the metabolism of plants.
- Because water requires a specific amount of heat energy to evaporate, it has a regulatory effect on high and low temperatures. During transpiration, water cools the surface of leaves which are inclined towards the sun.
- Water is essential for photosynthesis.

9. Irrigation also exerts a considerable influence on the human ecological systems, especially in arid and semi-arid regions. Related to this, the symposium entitled "Arid Land Irrigation in Developing Countries", which was held in Alexandria, Egypt, in 1976, made the following recommendations:

- The economic conditions for social development should be improved.
- The exchange of goods for food produced from irrigated soil should be made possible.
- Agricultural production should be stabilized by the prevention of losses incurred because of drought.
- The population's standard of living should be increased.
- Nomadic tribes should be evacuated.

10. Irrigation causes improvements to take place in the lives of farmers and their families. Irrigation schemes also modernise agricultural cultivation and effect a rationalisation of agricultural production when taken in conjunction with a higher level of education for the local population.

Water economy schemes

11. Water economy schemes, which form an organic part of irrigation schemes, are expanding more and more. In 1975 it was estimated that 245 million hectares of cultivated land were being irrigated: this amounted to 16.6 per cent of a total of 1,473 million hectares of cultivated land. From current situation and trends in development, it can be foreseen that the yearly growth in irrigated land will amount to about 10 million hectares. On the basis of this assumption, about 500 million hectares of land will be irrigated by the year 2000: this represents double the number of hectares irrigated in 1975. Assuming that 4,500 m3 of water is required per year for 1 hectare of land (450 l/m2 or 450 mm) then 45,000 million m3 of water will be used per year to irrigate 10 million hectares of land - by the year 2000, one billion 1,125 million m3 of water. This amounts almost to the yearly flow of the Rio de la Plata, or to five times that of the Indus, or 14 times that of the Nile.[1/]

12. Since such colossal amounts of water must be used for irrigation and because of the actual conditions facing farmers in arid and semi-arid regions, it is essential to switch over to water-saving schemes such as sprinkler systems and automatic sprinkler machines. Using this system, the exact amount of water required can be set and water loss through leakage or evaporation will be kept to an absolute minimum.

Soils permeability

13. A permeability problem in soils occurs when the rate of water infiltration into and through the soil is reduced by the effect of specific salts or a lack of salts in the water to such an extent that the crops are not adequately supplied with water and yield is reduced. It may lead to cropping difficulties through crusting of seed beds, water logging of surface soil and accompanying disease, salinity, oxygen and nutritional problems. Low salt

water levels can result in poor soil permeability due to the tremendous capacity of pure water to dissolve and remove calcium and other solubles in the soil. Carbonates and bicarbonates can also affect soil permeability. To determine the long term influence of water on soil permeability, 3 factors are of importance:

- Sodium content relative to calcium and magnesium
- Bicarbonate and carbonate content
- The total salt concentration of the water.

14. An infiltration rate of 2.5 mm/hour is considered low while 12 mm/hour is relatively high. For Sodium Absorption Ratio (SAR) greater than 6-9, the irrigation water could be expected to cause a permeability problem on shrinking-swelling types of soil (montmorillonite).[2/]

Salt content of irrigation water

15. The mineral salt content of ground water exerts a significant influence on the eco-system. In arid regions, irrigation may result in a rise in the ground water level; this in turn causes a rise in mineral salts on the soil surface. Deterioration in the quality of the water in the root area of crops occurs, because of mineral salts, fertilizer sediment and pesticides.

16. Salination and alkalinisation of soil have an unfavorable influence on the development of the eco-systems of cultivated crops. If the amount of salt in the soil is greater than about 0.5 to 1 per cent, eco-systems do not develop.[2/] Even a salt content of 0.2 per cent (choride, H-salts) has a damaging influence. Soluble salts also influence the supply of water to crops. In the case of higher concentrations the osmotic pressure increases.

Irrigation schemes and efficiency

17. Irrigation schemes have achieved very variable levels of efficiency in the last few decades, particularly because efficiency levels are dependent on soil type and method of irrigation. On average it can be assumed that only about 30 per cent of the water supplied is really absorbed by the crops.[3/] In countries with primitive methods of farming and irrigation, the percentage is even worse. According to a study from the Food and Agriculture Organization (FAO), only about 40 per cent of the water supplied to distribution networks actually reaches the irrigation areas. Effective water use of 10 to 20 per cent is exceptional and agricultural irrigation enjoys the reputation of incurring the greatest waste of water. What can be done to raise the total efficiency of water use?

- Replacement of conventional surface irrigation by sprinklers which are far more efficient
- Improvement of the accuracy and reliability of the optional irrigation scheme in terms of timing and quantity
- Automatic control of irrigation by using fully automatic sprinkler equipment.

18. In the United States of America, the ratio of land irrigated by sprinklers to land irrigated by surface irrigation altered in the period between 1958 and 1969 from 1:10 to 1:5.4. For an expected doubling of irrigation areas by the year 2000, an increase in water consumption of only 5 per cent is expected. This increase will almost entirely be supplied by a new water-saving system.[4/]

19. A sprinkler system can supply water to soils at rates equal to, greater or less than the infiltration rate. It can be operated automatically or manually. In general a sprinkler system can be employed for most soil and topographic conditions and for those areas where surface irrigation may be inefficient and expensive.

20. The high degree of water control is the outstanding advantage of sprinkler over surface irrigation methods. Water application rates can be as low as 2.5 mm/h, thus avoiding the hazard of soil erosion or excessive water loss. Sprinkler systems generally utilize smaller amounts of water more effectively than surface irrigation methods and are advantageous in the case of soils with high permeability or low water-holding capacity. When labour costs are high for surface irrigation, sprinkler irrigation may be the most economical method of supplying water.

21. Sprinkler systems can also be used when employing pesticide for frost protection and temperature control. Sprinkler systems also have some disadvantages. For example, damage to citrus was observed when poor quality irrigation water was sprayed on the foliage.[5/] In other cases poor quality water will leave undesirable deposits on leaves, fruits and crops.[6/]

22. If excessive quantities of soluble salts accumulate in the root area, the crop has difficulty in extracting enough water from the salty soil solution. A reduction in the plant's water intake can result in slow or reduced growth and may also be indicated by symptoms similar to those of drought. A bluish green colour and heavier deposits of wax on leaves appear on many plants.

23. If water tables are as close as two meters from the soil surface, they can become an important source of additional salt in the crop root area.[10/] When water tables exist within the two meter depth, salinity problems will occur even when irrigation water quality is good.

Irrigation-salinity problems will occur at

(EC_w mm hos/cm*)[2/]	(less than	0.75	No problems
	(	0.75 to 3.0	Increasing problems
	(more than	3.0	Severe problems

---

* EC_w = Electrical conductivity of irrigation water in mm hos/cm
1 mm hos/cm = 1 ms/cm (milli siemens pro cm).

24. With shallow water tables a salinity problem may exist due to upward movement of water and salt. Such a problem is related to high water tables and lack of drainage and is only indirectly related to salt in the irrigation water.

25. The advantages and disadvantages of sprinkler systems are as follows:

(a) Advantages

- Independence from surface conditions. No levelling work is required. Both uneven and sloping ground can be sprinkled.
- Total exploitation of the irrigation area as ditches and dams with embankments are not required.
- It is possible to use sprinkler systems on light and even ground.
- Soils with low water-holding capacity and soils which cannot be levelled may be sprinkled.
- Optional use of the sprinkling equipment on different areas.
- Multi-purpose sprinkling: sprinkling systems can be used to spray fertilizers and plant-protective agents as well as for temperature control and frost protection.

(b) Disadvantages

- High purchase and running costs.
- Qualified personnel required to maintain systems.
- The adverse effect of wind: the use of sprinkling systems is restricted by strong winds.

26. Automatic and semi-automatic sprinkling systems are also available. These systems make possible quantitative and accurately-timed distribution of water to crops.

27. Salt tolerance in agricultural crops is very wide. This wide choice expands greatly the usable range of water quality for irrigation. For example, water of EC_w 1.5 - 2.0 which is unsuitable for the production of a salt-sensitive crop, field beans, ground nuts, may be acceptable for corn, cotton or sugar beet. Sensitive crops could be grown but yield might be reduced to about 50 per cent.

Appropriate irrigation schemes for selected types of crops

28. Perennial forage crops. Perennial grasses and legumes used in forage production have small seeds and, therefore, require careful seedbed preparation. The most common cause of failure to establish perennial forage crops is a deficiency in soil water caused by a loose seedbed. If the surface is dry, early irrigation is necessary to guarantee regular germination, but irrigation is never a substitute for good agronomic practices.

29. Generally the best time to seed forage crops is springtime with good ground water conditions. If the ground water is not adequate to develop alfalfa to the 3-4 leaf stage, irrigation is a necessity. A sprinkler system is preferable for better water distribution and uniform moistening of the upper soil layer.

30. As alfalfa is one of the most important forage crops, irrigation practice is well-known. Alfalfa is a very deep-rooted crop, 8 to 12 feet, and irrigation should be adequate to charge the full root area. The amount of water and the irrigation cycle depend on the depth of rooting and the water-holding capacity of the soil. Values for these parameters as well as for evapo-transpiration rates are published by FAO.[7/]

31. All forage species capable of high production respond to irrigation, especially in arid areas. Reports from California show an increased alfalfa yield of 5t/acre after supplying 760 mm water per year.[8/] Normal yield in rainy conditions is 5 to 6t per hectare. In the western mountains alfalfa yielded 4.5t per acre after being given either 3 irrigations of 13 mm each or 5 irrigations of 8 mm.

32. **Grain and field crops.** This section presents information about the irrigation of corn (Zea moys), sorghum (Sorghum vulgare), rice (Orysa sativa), wheat (Triticum vulgare), barley (Hordeum vulgare), potatoes (Solaisum tuberosum), field beans (Pluaseolu vulgare). Apart from rice, the crops considered in this chapter are irrigated specifically to maintain favorable ground water conditions for crop growth. In the case of rice, flooding assists in controlling weeds.

33. The growing season influences strongly the frequency and quantity of irrigation use because of variations in evapo-transpiration levels (ET). Depletion of a quantity of water in midspring by winter wheat with full vegetative cover requires two or three times as long as corn or surghum in midsummer. Winter small grains are normally grown in temperate regions for 4 to 12 weeks during the fall months. Low evaporation and only partial vegetative canopy results in low ET, seldom exceeding 0.2 cm per day. ET rate during the winter period is generally in the range of 0.02 to 0.1 cm daily. Full vegetative cover is soon attained if climatic potential is favorable and the ET rate generally follows the climatic conditions until the crop begins to mature.

34. Corn, sorghum, potatoes and field beans grown in temperate climates are seeded in late winter or spring and harvested in midsummer. Full vegetative canopy is achieved 6 to 12 weeks after emergence depending on the climate.

35. **Sugarcane and soya beans.** Sugarcane (Saccharium officuarum) is a tropical crop which is grown between 30° N and 30° S latitude. It is a fibrous rooted crop whose roots are most active in the first 2-3 feet of surface soil.

36. ET rate represents the quantity of water which must be applied at suitable intervals to maintain a ground water balance favorable to plant growth. A lot of studies have been carried out to explain the water yield relationship. The Hawaian Sugar Planters Association in 1963 studied the matter under a controlled temperature (19.6 to 23.8 C) and showed that 135 g of water produced 1 g of dry matter (Transpiration dry matter production study).

37. For a 2 year crop small plot testing phase, 216 to 260 cm of irrigation water provided by 35 to 44 irrigations were needed to supplement an annual rainfall of 49 cm. Under these conditions approximately 100 lb of water produced 1 lb of cane.[9/] Seasonal water used by soya beans ranges between 50 to 76 cm [10/] and 33 to 60 cm with rates averaging 0.75 cm/day during July and August in Missouri, USA.[11/] In Kansas the estimated water requirements are 50 to 60 cm with peak use of 0.75 cm/day. Grisson calculated the water use for optimal growth in Mississippi as 16.2/17.8/16.0 cm for June, July and August respectively.

38. This data indicates that the amount of water used by soya beans is quite similar to that used by other crops grown at the same time. A common cause of reduced yields through lack of moisture is a reduction in seed weight. Witt 1954 reported that in non-irrigated plots, seed weight and yield were reduced by one third in comparison to irrigated soya beans.

39. Cotton (Gossypuim Sp) provides an excellent example of a crop where research has developed optimal production by introducing adapted irrigation practices. In areas where cotton is grown with natural rainfall, irrigation may be beneficial when applied at the time of need; under semi-arid to arid conditions, irrigation is essential to grow cotton. Since early root development in cotton is extensive, the soil should be moistened prior to planting by preplanting irrigation. The advantage of preplanting irrigation was shown by Nagle, 1954, in Queensland, Australia. Preplanting irrigation is important to a favorable salt balance since the infiltration rate is highest during this irrigation.12/ Preplanting irrigation consolidates the soil disturbed by deep tillage and land preparation, thereby improving planting conditions.

40. The amount of water is low during emergence and early plant growth. Water used during this period is about 10 cm or approximately 10 per cent of the total water consumption. Soil water deficits occurring during the preflowering stage can cause yield reductions of between 22 and 39 per cent.13/

41. Half or more of the total water use occurs during the flowering stage which is the stage when the most rapid plant development and growth take place. Frequency of irrigation is determined by the water holding capacity, rooting depth, degree of plant cover and evaporative demand of the environment. Fiber and seed development takes place in the post-flowering period as the plant approaches maturity.

42. The water holding capacity of the soil root development and depth of water penetration generally determine the amount of each irrigation and the interval between irrigations, and will also determine the timing of the final irrigation. Early irrigation is harmful to yield and quality because some bolls might not mature properly; late irrigation in the post-flowering period might cause delay in the opening of bolls and greater susceptibility to frost damage and lodging.

43. Vegetables are high value crops and are grown wherever people live. An adequate water supply is one of the main requirements for growing vegetable crops successfully. Vegetable production demands a large outlay of capital and, if water is not available at the right time, this investment is no longer safely protected. A further benefit of irrigation is that good vegetables are tender, crisp, succulent, free from excess fibers and mildly flavoured. Without an ample and uniform supply of water and plant nutrients in the root area, this would never be realised.

44. Perennials such as asparagus, artichokes and rhubarb have extensive root systems and require open, well-drained soil for optimal growth. Roots occupy such a large volume of soil that irrigation requirements are lower than for annual vegetables. Potherbs or greens (Spinacia oleracea, brassicaol), mustard (B. Juncia), are shallow-rooted. These crops are usually grown during the cooler part of the season when ET rates are low. Salad crops, apart from lettuce (Lactuca saliva), celery, endive and parsley are long season crops with limited root systems. Irrigation is necessary for maximum yields. Crops with shallow-root systems (celery, lettuce) are more susceptible to drought injury than deep-rooted crops (asparagus, tomatoes). Irrigation increases the quality of leafy crops which should be crisp and tender at harvest.

45. Cruciferae like cabbage, cauliflower, brussel sprouts and broccoli (Bramica oleracea spp) grow best in a cool, moist climate and well-drained soil. Roots are shallow to moderately deep. For top yields, irrigation is essential since a high level of soil water is necessary.

46. Legumes like beans (Phaseolus vulg., ph. limeusis, ph. lumatus) or peas (Pisum salivum) are rapidly growing vegetables with relatively limited root systems. Snap beans responded to irrigation in 18 out of 30 different trials in the North-East of USA. The maximum increase in yield was between 36 to 64 per cent depending on the different areas.

47. Tomatoes (Lycopersicon esculentum) are long season deep-rooted plants with high water requirements. Yield increases of 7.8 t/acre or 67 per cent were obtained in different trials in North-East of the USA during 1956-1960.[6]

48. Cucumber (Cucumis sativus), melon and water melon are long season crops with medium or deep root systems that require large amounts of water; irrigation not only increases their yield but also the quality.

Summary

49. The need for irrigation is influenced by many factors interacting in a complex way. The amount of water required for vegetables and the frequency of irrigation vary considerably according to the local climate, soil conditions etc. It is, therefore, impossible to make specific recommendations. Two characteristics should be used as guidelines to irrigation requirements:

- The depth of the soil profile and the amount of water that it can store;
- The depth to which the roots can penetrate.

50. Deep-rooted crops growing in deep soils filled with water may require little irrigation or none at all. Shallow-rooted crops on the same soil will usually benefit greatly from several irrigations. Shallow soils require frequent irrigations for both deep or shallow crops.

II. A BRIEF DESCRIPTION OF THE VARIOUS SPRINKLER AND DRIP IRRIGATION SYSTEMS

General

51. There is no accepted uniform international standard for the technical layout and various systems and processes of modern irrigation. In the present report, under the designation "rain irrigation" or "modern irrigation system", all necessary and relevant machinery and equipment for the operation of field irrigation is to be understood. This includes all components as well as water supply and distribution. Figure 1 (page 19) depicts the most important modern irrigation systems and their designation. In this report, modern irrigation or rain irrigation has been classified into two distinct types, viz:

A. Sprinkler Irrigation

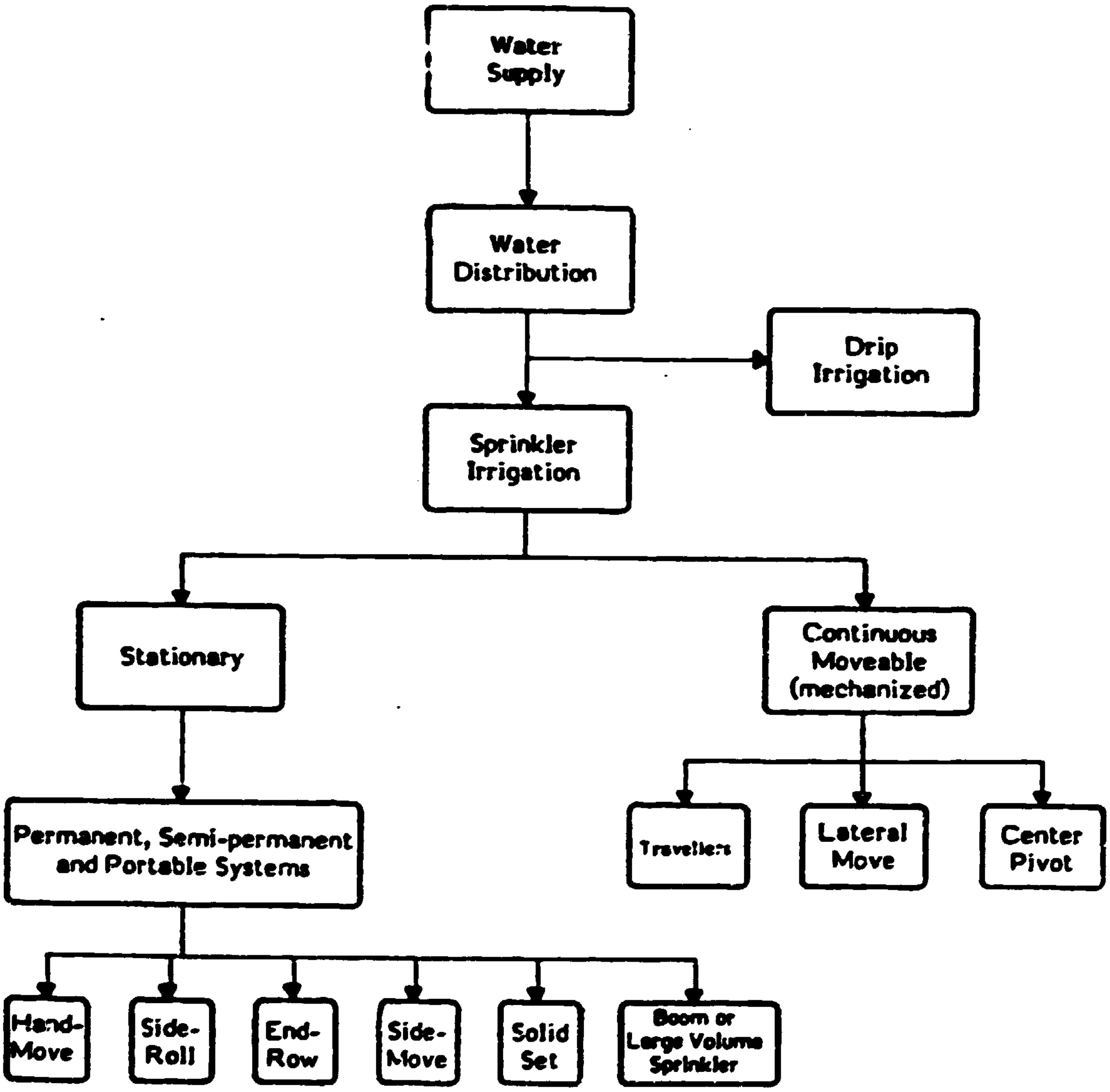
B. Drip Irrigation.

Each of these two types of irrigation has been dealt with separately in the following sections.

A. Sprinkler irrigation

52. A sprinkler system is a network of tubing or pipes with sprinklers or nozzles attached for spraying water and/or liquids over the land's surface. It is made from many different components. Beginning at the water spray from nozzle and tracting the system to the water source, there are sprinklers, pressure of flow regulators, riser pipe, couplers, tubing and fittings. These components make up that part of the sprinkler system called the sprinkler lateral. The sprinkler lateral is connected to a valve tee or elbow to the main pipeline which is connected to the water supply source. Sprinkler laterals are the part of the piping system that carries the water to the sprinklers, spray nozzles or perforations from the supply or distribution main pipelines.

Figure 1. Modern Irrigation Systems



53. Agricultural sprinkler systems are classified into two general groups. One group applies water only while the sprinkler lateral is stationary. The other group applies water while the lateral is continuously moving.

A.1. Stationary lateral sprinkler systems

Installation characteristics of sprinker systems

54. According to the way the system is installed and (operated), stationary lateral sprinkler systems can be classified as permanent, semi-permanent or portable.

55. **Permanent systems** are those made up of permanently located piping systems, usually buried. Some overhead piping systems are used in nurseries. The risers and sprinklers are located permanently. Irrigation skilled labour shortage has increased the number of permanent systems in use today.

56. High initial installation costs must be offset over the life of the system by labour savings and increased quality and quantity of crops produced. Permanent systems have brought the multiple use concept to the irrigation field by permitting the irrigation equipment to be used in applying fertilizers, environmental control, weed and insect control, in addition to their original irrigation water application functions. All of these additional uses reduce production costs and help amortize the original system investment.

57. **Semi-portable systems** are made up of both permanently located piping and portable piping which together make up either a field or farm system. Most semi-portable systems have a permanent main line and sometimes sub-mains with portable sprinkler laterals. Legally, the definition of semi-portable, permanent and portable systems can be important in determining whether the system is appurtenant to the land or detachable. Main lines, although intended for one location, would be classified as portable if bolted together and laid on the ground surface.

58. **Portable sprinkler systems** are those made up entirely of portable piping from the pumping plant or water-pressure source to the last sprinkler. To be portable, the pipe connections are not necessarily "quick coupling" as long as they can be connected or disconnected manually and reassembled at other locations. It should be noted that the definition of a portable sprinkler system includes only the piping system, and that the source of water pressure may be portable or permanent. In some instances, where gravity or community line pressure is utilized, a pumping plant may not be involved as part of the system.

Piping and tube characteristics of sprinkler systems

59. Sprinkler systems can also be classified according to the pipe and tube arrangements, layout and to the material used, viz:

- Stiff pipe systems (steel, aluminium or PVC tubing)
- Stiff pipe + flexible pipe systems
- Flexible pipe systems.

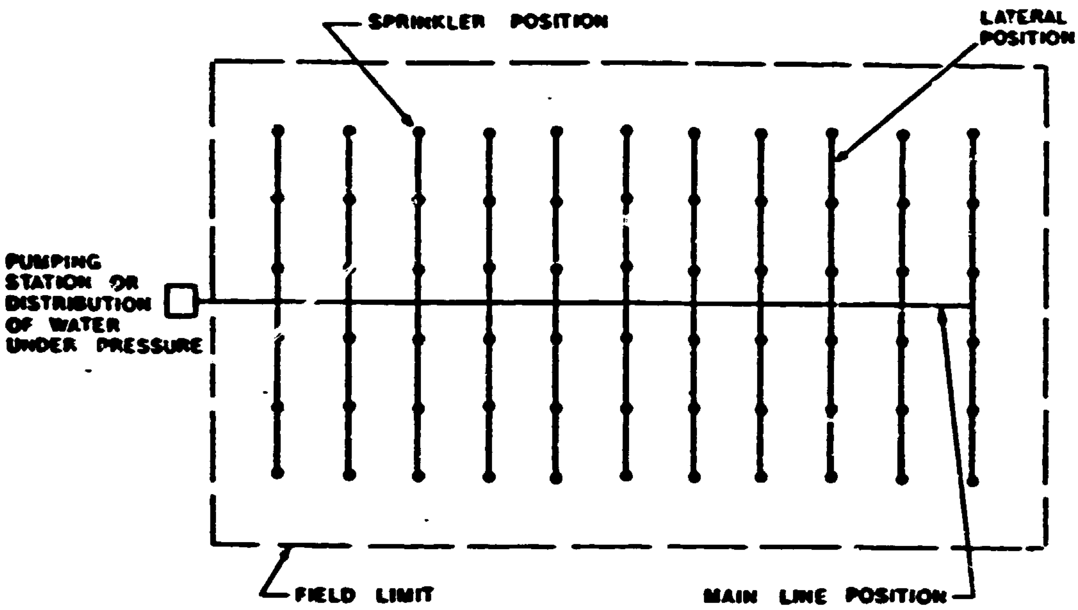
Operational characteristics of sprinkler systems

60. According to the different modes of operation, the stationary lateral sprinkler system can be classified into:

- Hand-move
- Side-roll
- End-tow
- Side-move
- Boom or large volume sprinklers
- Solid set.

61. **Hand-move laterals** are moved entirely by uncoupling, picking up and moving section of the lateral pipe with hands requiring no tools. The quick-coupling portable type of lateral used in the head type of sprinklers is now the common type of lateral used. A general layout of the pipe network is shown in Figure 2.

Figure 2. Field Layout of Non-mechanized Sprinkler Equipment



In order to carry out one complete application of water to the field, a larger or smaller fraction of the equipment is transferred and re-used in different positions.

Figure 3. Layout of an Entirely Mobile Pipe Network

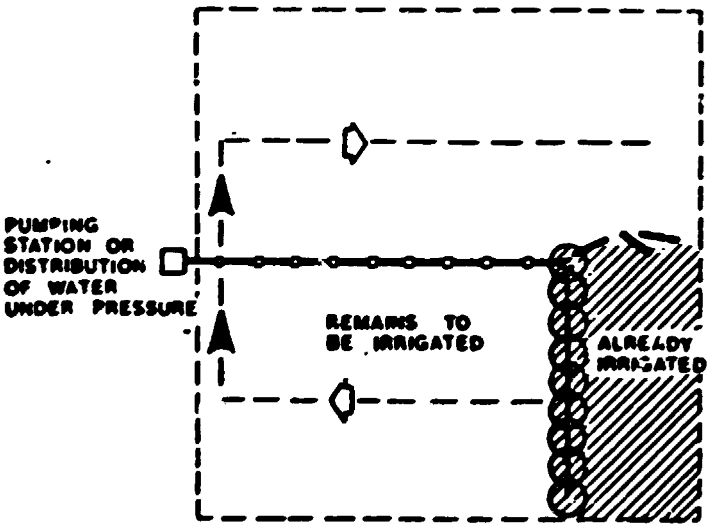


Figure 4. Layout of a Pipe Network with Mobile Sprinkler Laterals

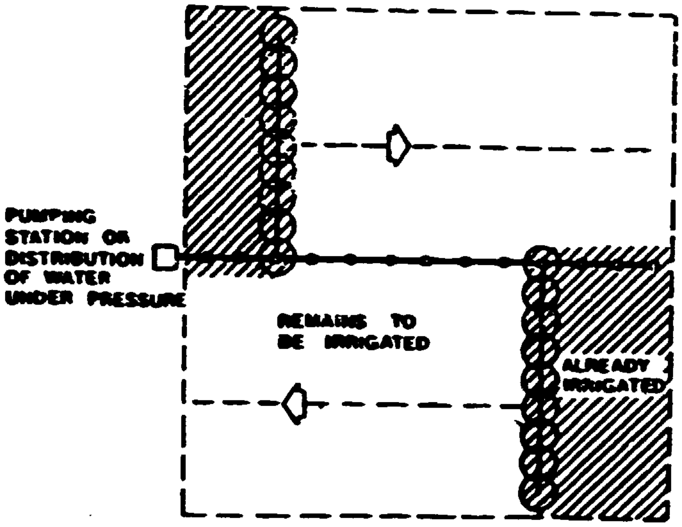


Figure 5. Layout of a Pipe Network with Mobile Sprinkler Heads (Total Cover)

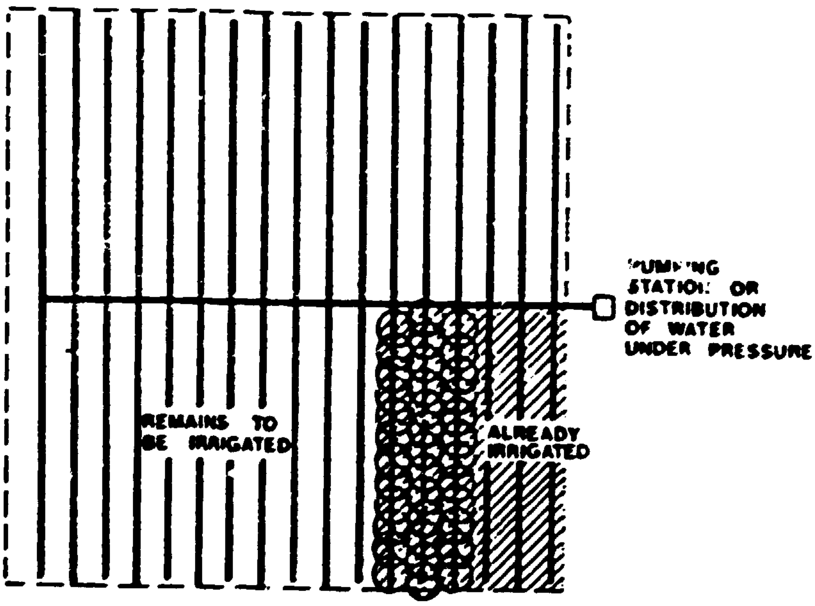


Figure 6. Layout of an Entirely Fixed Pipe Network (Solid Set)

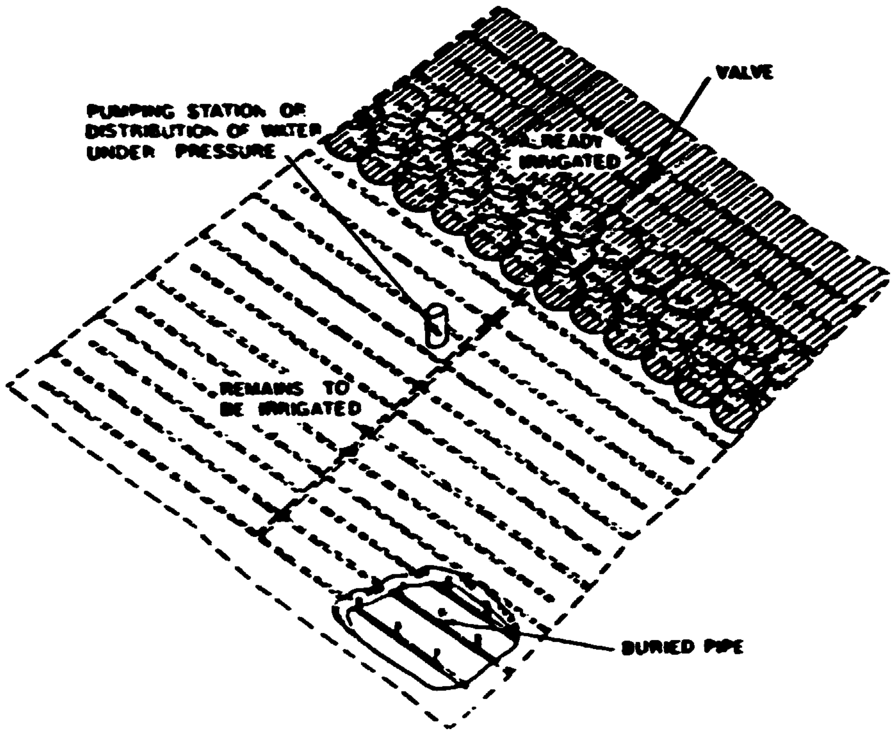
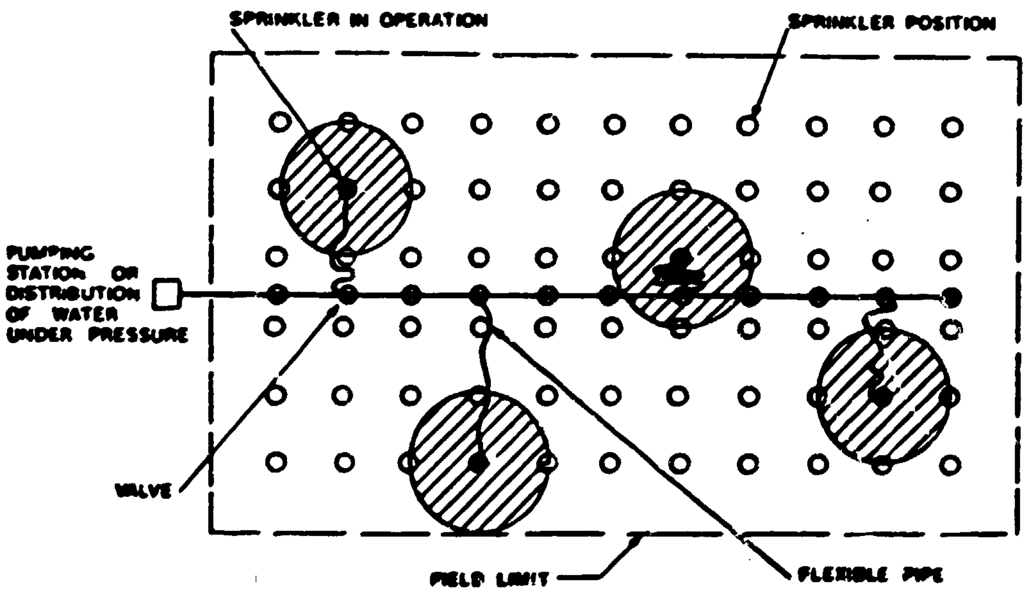


Figure 7. Layout of a Pipe Network with Sprinklers Attached to Flexible Pipes



62. In these systems, a larger or small part of the system may remain fixed but the more one uses the same equipment for different positions, the more labour will be required to move it.

The principal operating techniques are presented below:

(i) All equipment is used in several positions during the irrigation season, sprinkler laterals being used in more positions than the conveying pipes (see Figure 3, page 22);

(ii) During the irrigation season sprinkler laterals and sprinkler units are used in several positions together with fixed conveying pipes (see Figure 4, page 23);

(iii) Sprinklers are used in several positions, while the other equipment remains fixed throughout the irrigation season (see Figure 5, page 23);

(iv) All equipment remains in place throughout the irrigation season, while only the valves are manipulated to open or close the irrigation on the sprinkler laterals (see Figure 6, page 24). This system is called solid set and is presently used widely.

(v) In the specific case where sprinklers are attached to flexible pipes and all supplying pipes remain stationary, sprinklers are moved by one man hauling on the flexible pipes (see Figure 7, page 24).

63. The side-roll wheel move was one of the first mechanized sprinkler laterals to be placed on the market. This lateral utilized the pipe as an axle, with the wheels being placed at each coupler or fastened around the pipe away from the coupler. Where wheels were placed at the coupler, the wheel hub and coupler were combined and designed to be quick coupling. The size of wheels available varies from 46 to 84 inches (1.2 to 2.1 meters) in diameter. The larger wheels are required to allow passage over some of the higher growing crops.

64. End-tow lateral systems may be either of the <u>drag-type</u> or the <u>pull-type wheel</u> system.

65. **Drag-type.** The principle of operation is to pull the entire line from one setting to another, across the main line, swinging over into the new lateral position as the line is pulled forward, in the same manner as trains are switched from one track to another.

66. **Pull-type wheel systems** operate the same as the drag-type but with supporting wheel carriages to raise the pipe off the ground during moving. Wheel carriages differ in design and resulting flexibility.

67. **Carriages with trailer line or side-move laterals** were developed to reduce the labour required for lateral moving. The lateral is moved by a motorized drive shaft that extends the length of the lateral and drives each carriage wheel by means of belts or chains and gears. Some laterals have a quick power disengagement lever that permits the freeing of any wheel to allow for realignment of the section of the lateral while being moved. The carriage wheels on some models can be turned 90 degrees to permit end towing from one field to another after the trailer pipelines have been disconnected from main lateral pipeline and stored on the carriage racks.

68. Solid-set or rotating **boom-type laterals** consist of a tower and cable arrangement to hold the laterals in place. The boom is rotated by the jet action of the many nozzles on the boom. The booms are of various length depending on the acreage desired to be covered at each setting. Some booms can be lowered for transporting beneath power or telephone lines. The boom is transported on a trailer which may also be used as a pipe carrier.

69. **Boom or large-volume sprinkler laterals** have the sprinkler mounted on a wheel cart or trailer and are moved from set to set by hand or tractor. The large sprinklers are sometimes used for farm waste water disposal. Spacing of sprinklers on the lateral depends on the type of sprinkler, size of sprinkler nozzle and operating pressure.

70. Of the systems described above, hand-move irrigation and solid set are now the state of the art and commonly used. For mechanized systems, the continuously moving laterals are now the state of the art which have been dealt with in the following paragraph.

A.2. Continuously moving laterals

71. Continuously moving laterals are a special type of mechanized sprinkler lateral that remains connected to the main pipeline and continuously move while water is being applied. This contrasts with the previously described mechanized sprinkler laterals that have to be disconnected from the main pipeline each time it is moved. Development of moving laterals was advanced by the development of lightweight high-pressure hose. Types of continuous laterals are:

- Center pivot
- Straight-line linear move, and
- Traveller.

72. Mechanization of farm operations as labour costs increase, together with the shortage of labour for moving portable laterals and sprinklers, have resulted in improved and increased use of continuously moving sprinkler systems. These systems are characterized by laterals and sprinklers that remain connected to the main pipeline, but continuously move while applying water.

73. The center pivot system was first patented in 1952. Use of center pivot systems has risen rapidly in recent years, primarily because of their low labour requirements. Once irrigation parameters are entered into their automatic control systems, center pivot systems are capable of operating for long periods of time with minimum attention.

74. This type of system consists of a single sprinkler lateral with one end anchored to a fixed pivot structure and the other end moving in a circle about the pivot. Water is supplied to the lateral at the pivot point (see Figure 8, page 29). The lateral is supported by towers and cables or trusses which move on wheel, tracks or skid support units located 80 to 250 feet (24.4 to 76.2 meters) apart along its length. Lateral lengths vary from 200 to 2,600 feet (61 to 792.5 meters).

75. The lateral is kept in a straight line as it moves around the pivot point by an alignment system that speeds up or reduces speed of support units or starts and stops movement of the support units as required to maintain alignment. Should the alignment systems and support units get too far out of alignment, a safety device automatically shuts down the entire sprinkler system before the lateral can be damaged. A mechanism for propelling the lateral is mounted on each lateral support structure.

76. The five types of power units for propelling a center pivot sprinkler system are:

(a) Hydraulic water drive
- piston
- rotary

(b) Hydraulic oil drive
- piston
- rotary

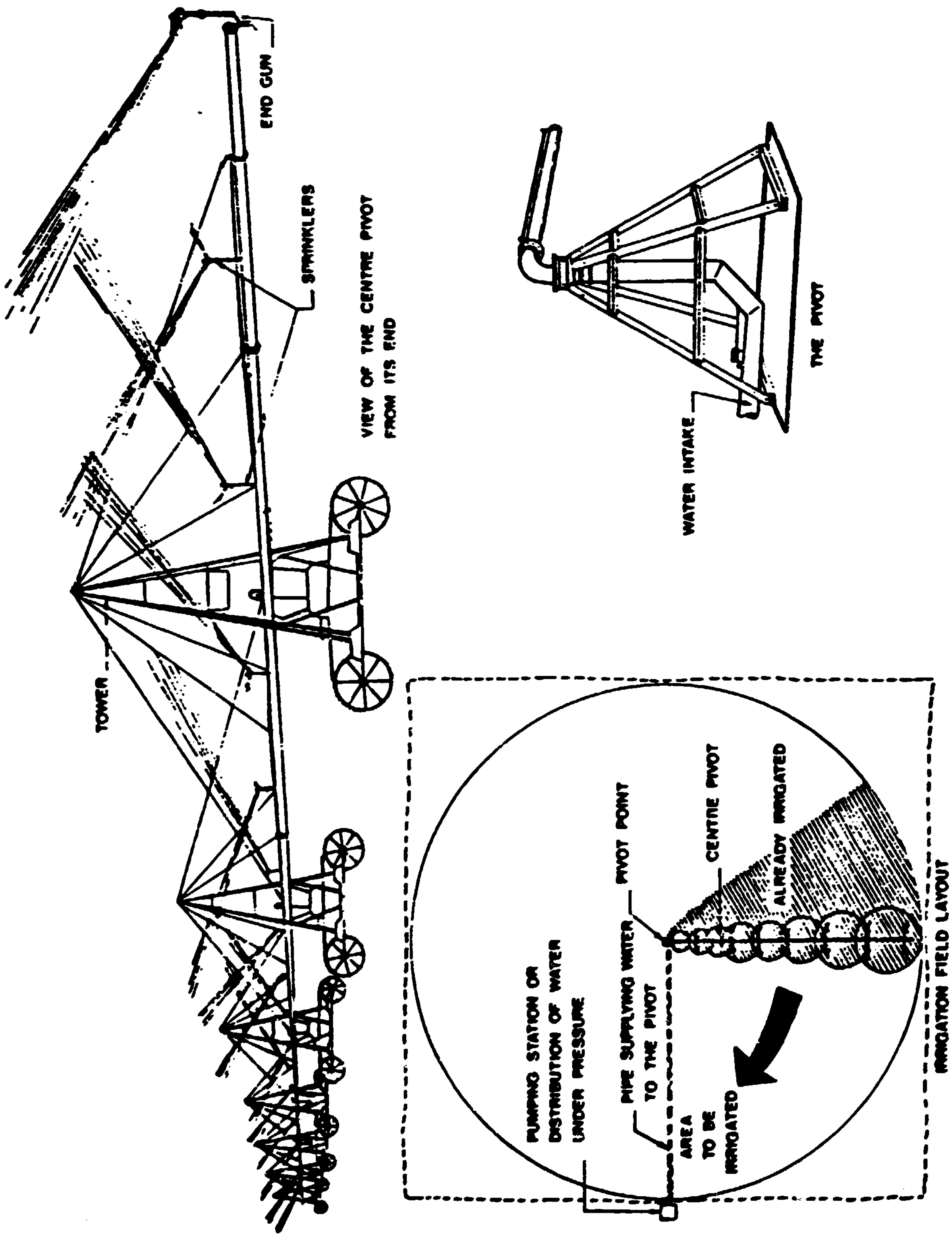
(c) Electric motor drive

(d) Air-pressure drive

(e) Mechanical or cable drive

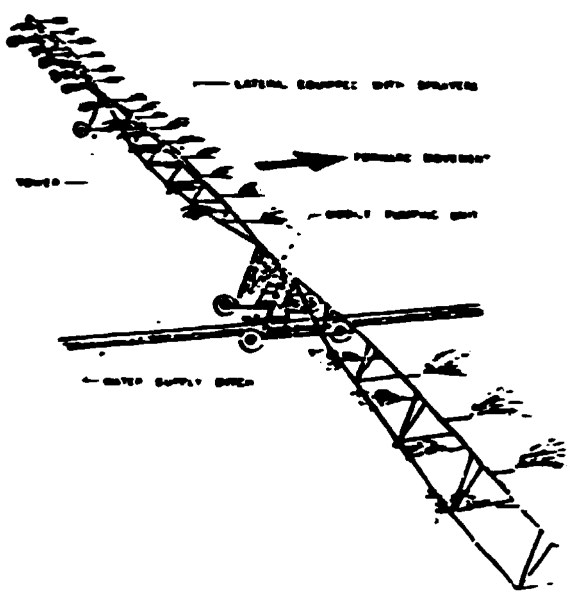
77. **Continuously moving straight lateral or linear systems.** The systems are similar to the center-pivot laterals in that the pipe is supported by towers and cable or trusses between towers mounted on wheels. There are three methods of supplying water to the moving lateral by pumping from an open canal (see Figure 9, page 30), through a long high pressure flexible hose connected

Figure 8. Center Pivot Irrigation



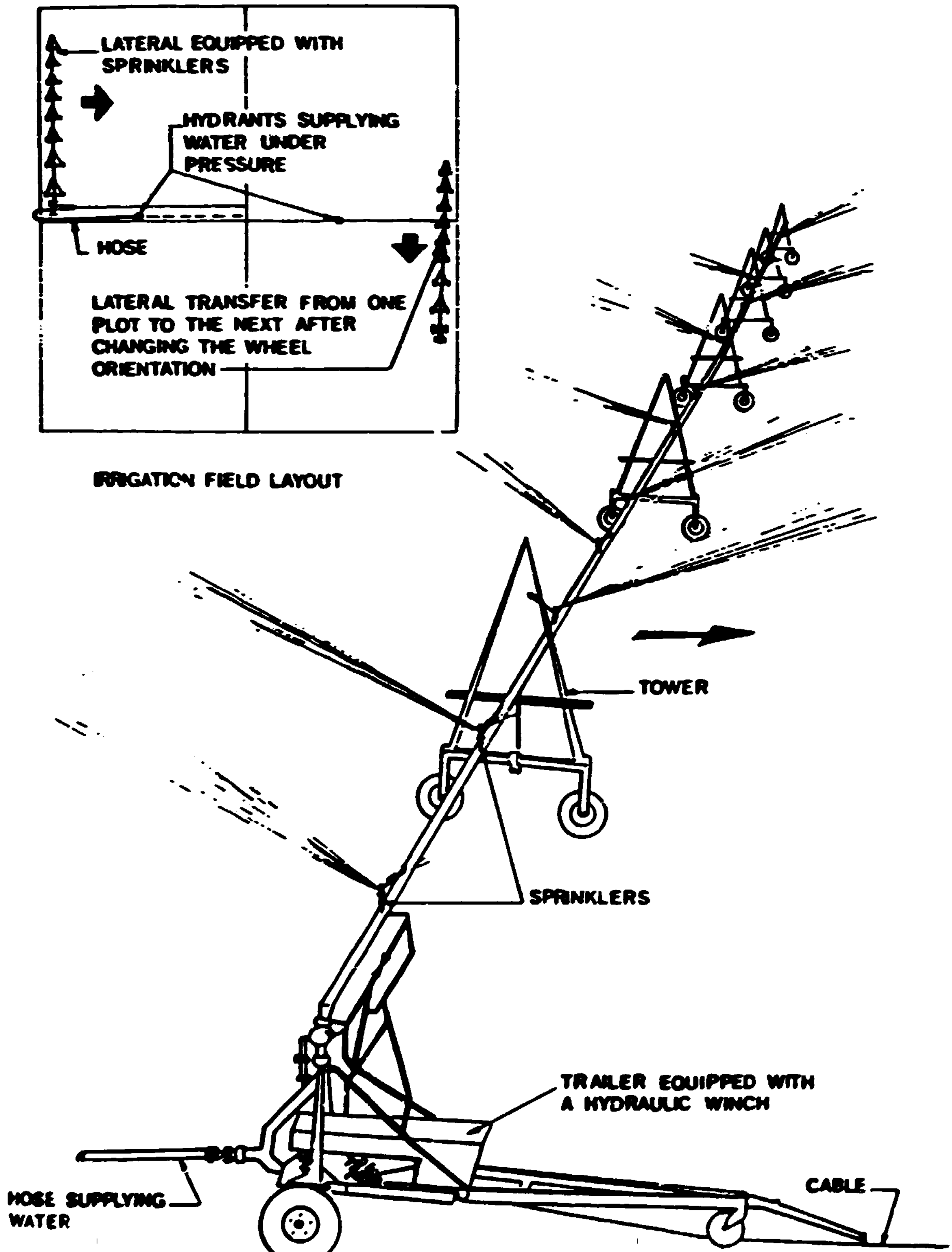
to risers from a main pipeline (see Figure 10, page 31) and a system that automatically connects and disconnects from riser valves from an underground pressure pipe.

Figure 9. **Lateral System Irrigating a Rectangular or Square Field during its Transit (Water taken up from a ditch)**



78. **Traveller sprinkler lateral systems** are powered track or wheeled vehicles that tow a high-pressure, flexible hose connected to the water supply main pipeline. The vehicle is towed by a power winch and cable or propelled by its own engine across the field at regular intervals, usually 330 feet (100 meters) apart, irrigating as it moves. The sprinkler is typically of the large volume or boom type, operating at pressure of 80 psi (552 kPa) or higher, delivering 300 to 1,000 gpm (1,136 to 3,785 liters per minute) or more, and covering a wetted diameter of 200 to 600 feet (61 to 183 meters). Figure 11 (see page 33) shows a reel type hose pull sprinkler.

Figure 10. Sprinkler Lateral Irrigation while Advancing at Right Angles to its Own Direction (Water Piped to the Machine by a Hose)



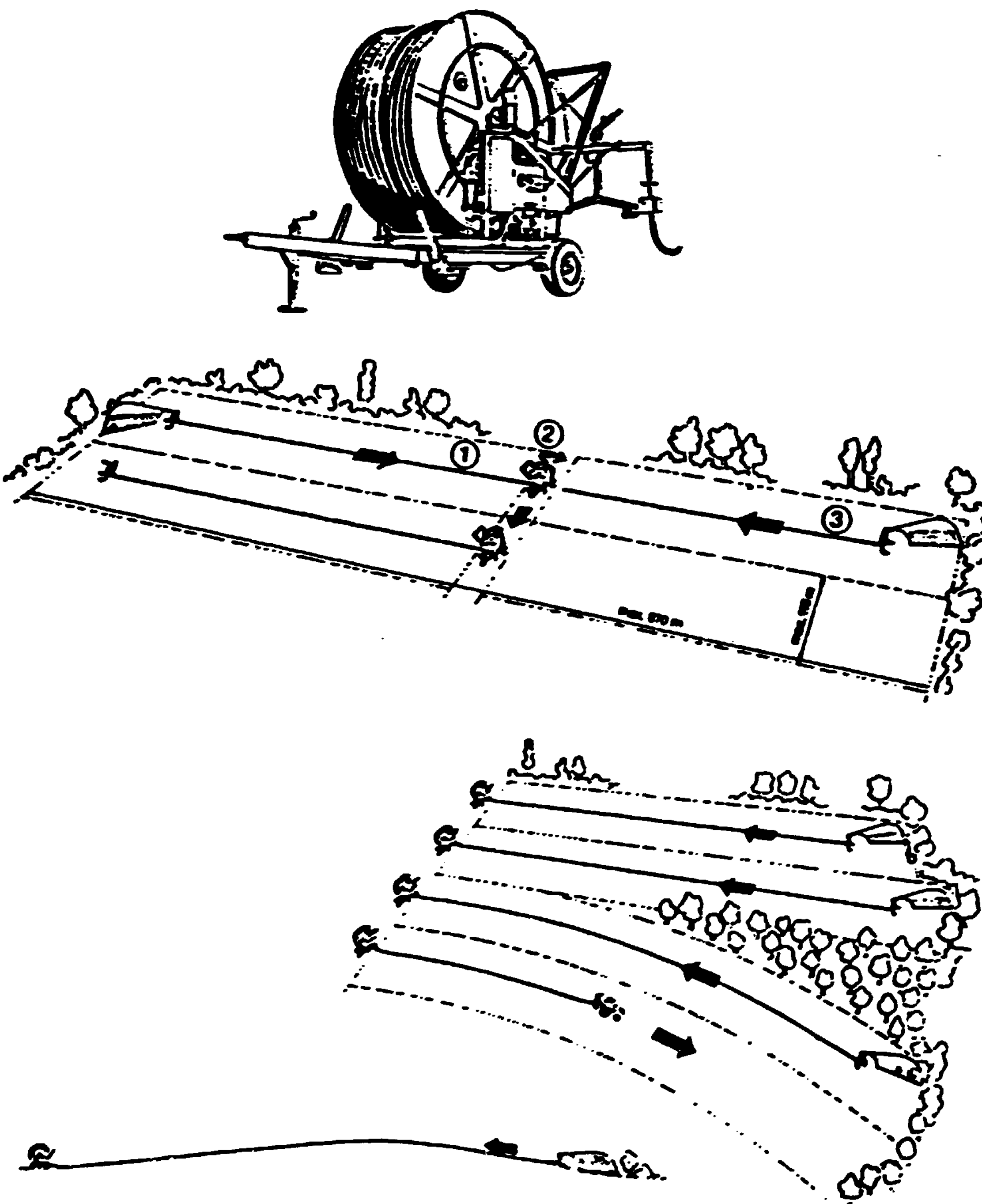
79. Traveller sprinkler laterals may have a long (up to 660 feet, 183 meters, or longer), flexible, high-pressure hose to connect the sprinkler on the vehicle to the water supply pipeline. It was the development of large diameter, high-pressure, flexible and wear-resistant hose that gave added impetus to the development of the traveller sprinkler systems. The high-pressure hose is made in 2.5 to 5 inches (63 to 127 millimeters) diameters. It is usually manufactured in one-piece lengths of 300 or 660 feet (101 to 201 meters).

Sprinkler applications

80. Apart from irrigation of fields and orchards, sprinkler equipment has many alternative uses, viz:

- Environmental modification
- Fertigation (fertilizers simultaneously applied during irrigation)
- Chemigation (chemicals simultaneously applied during irrigation)
- Land application of waste water and sludges
- Rural fire protection
- Dust control
- Cooling of animals in feedlots and on ranges
- Building cooling
- Soil compaction for construction sites
- Artificial snow-making
- Dewatering flooded areas
- Aeration of water
- Log curing
- Waste flush systems
- Nursery and greenhouse irrigation.

Figure 11. Traveller Sprinkler System



B. Drip or trickle irrigation (see Figure 12, page 35)

81. Drip irrigation is the precise, slow application of water as discrete drops, continuous drops, small streams, or miniature sprays through mechanical devices called emitters (drippers or applicators) located at selected points along water delivery lines. Emitters dissipate the pressure to allow low discharge rates. Types of drip irrigation methods include surface, subsurface, bubbler, spray, mechanical-move, and pulse systems.

82 In drip irrigation, the objective is to frequently supply each plant with sufficient soil moisture to meet evapotranspiration demands. Drip irrigation offers unique agronomic, agrotechnical and economic advantages for the efficient use of water. Fertilizer, or other chemical additives, can be applied directly onto or into the soil. It eliminates spray or running water down furrows and allows water to dissipate under low pressure. Water is carried through a pipe network to each plant. Advantages of drip irrigation systems include improved water application and distribution efficiency, improved water control, enhanced crop response, reduced weed growth, fertilizer application efficiency, potential usage of saline water, and reduced energy requirements. Possible disadvantages of drip irrigation systems are clogging, salinity build-up and restricted soil moisture distribution.

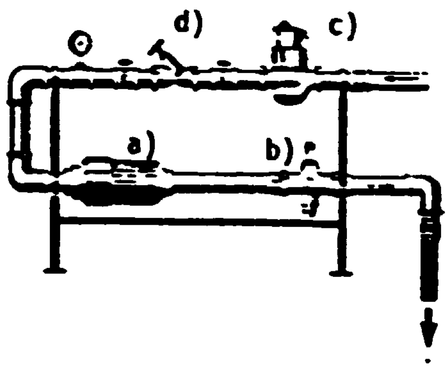
Types of drip irrigation systems

83. The primary types of drip irrigation systems and methods are:

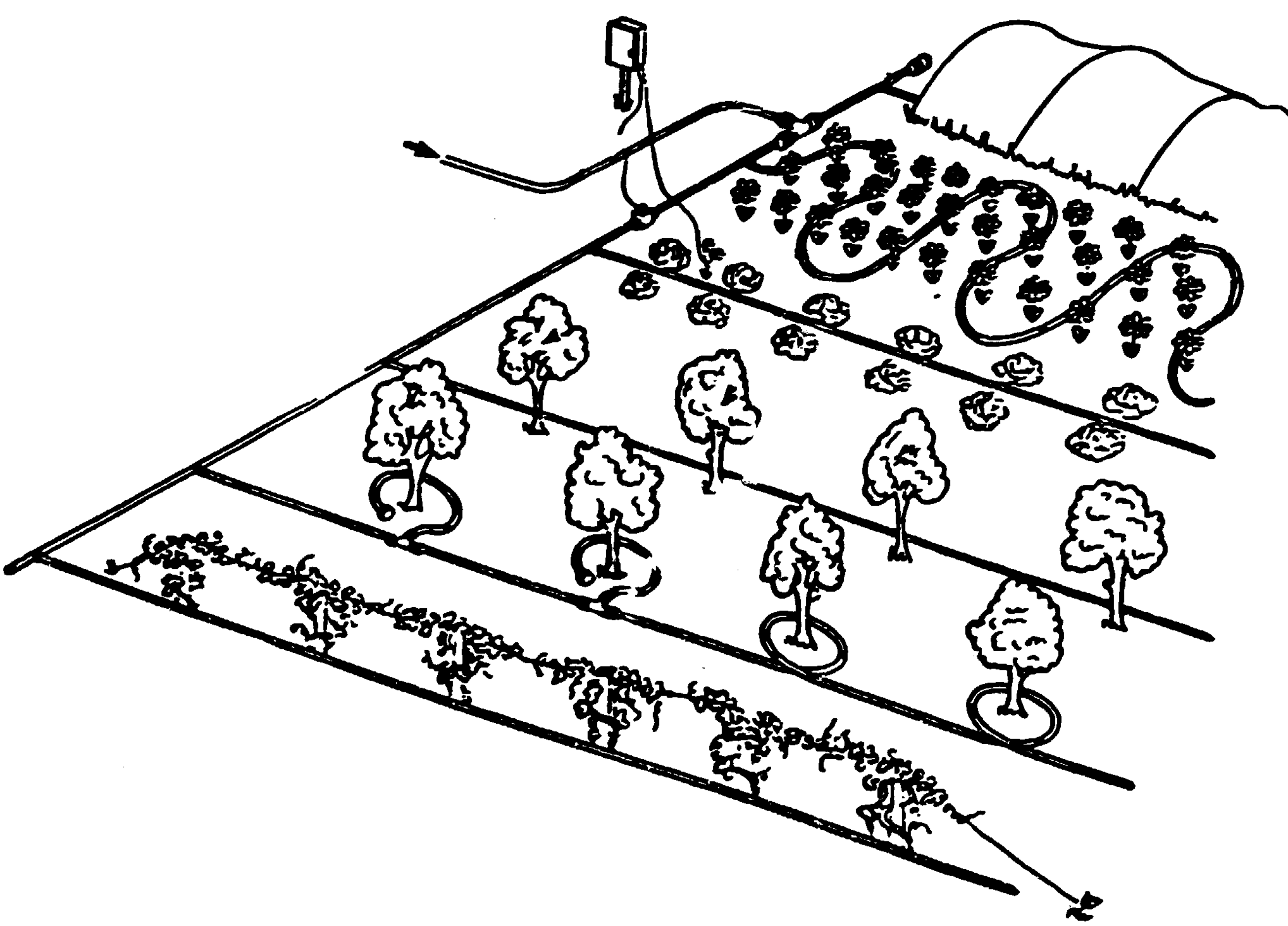
B.1. Static systems

84. **Surface systems.** The drip irrigation systems with lateral lines laid on the soil surface are the most common practice. Surface drip has been used primarily on widely-spaced plants but can also be utilized for row crops.

Figure 12. Drip Irrigation



a) Filter
b) Water regulator
c) Water meter
d) stop valve



Advantages of surface drip irrigation include the ease of installing, inspecting, changing and cleaning of emitters, plus the possibility of checking soil surface wetting patterns and measuring individual emitter discharge rates.

85. **Subsurface systems.** Lately, subsurface drip irrigation systems have gained wide acceptance. Earlier problems of clogging have been reduced, and these systems are now being used primarily on small fruit and vegetable crops. Advantages of subsurface drip irrigation include freedom from anchoring of tubing at the beginning and removing it at the end of the growing season, little interference with cultivation or other cultural practices, and possibly a longer operational life.

86. Subsurface drip irrigation is not the same as subirrigation, which is the irrigation through or by a groundwater table.

B.2. Moving systems

87. **Mechanical-move drip systems** for row crops are of two principle types. Center pivot and linear move sprinkler laterals have been modified to utilize trailing drip irrigation laterals rather than sprinklers or spray heads. Operating pressures are lower than those of most conventional sprinkler systems and the uniformity of water distribution over the field is usually good. Discharge rates from the travelling drip system often exceed the soil infiltration rate so that soil or metal check dams are required in the furrow to prevent soil erosion or water runoff. Potential advantages of travelling drip/sprinkler systems include a possible reduction in clogging problems and a less expensive pipe network, compared to soil-set drip irrigation systems.

Drip irrigation system components

88. The main drip irrigation system consists of emitters, lateral lines, main lines and the "head" or control station.

89. **Emitters.** The emitter controls the flow from the lateral to the soil. Emitters range from simple perforated pipe (line-source emitters) to individual or multiple outlet devices inserted into plastic pipes (point-source emitters). The emitter decreases the water pressure head from the lateral to the soil. This may be done by small holes, long passageways, vortex chambers, discs, steel balls, manual adjustment, or other mechanical means to reduce emitter discharge rates.

90. **Lateral lines** (usually made of plastic) have diameters of 0.2 to 0.75 inches (9 to 19 mm). Lateral lines are usually placed one or two per tree or plant row and may go long distances because the flows are low; however, lateral lines are seldom longer than 1,000 feet (300 meters).

91. The **main lines** carry water to the lateral lines from the head. They are usually made of plastic and are buried. Their size depends on the required water flow to the laterals.

92. The **control station** or "head" of the system is where the water is measured, filtered or screened, treated and regulated as to pressure and timing of application.

III. FACTORS TO BE CONSIDERED IN THE SELECTION OF SPRINKLER IRRIGATION SYSTEMS

93. Selection of the proper sprinkler system and its layout is based on many different factors. The most important factors bearing upon layout and selection which should be considered are the following:

Effect of land slope

94. Slope is a measurement of the difference in elevation from one point to another. It is generally expressed as a percentage - the number of feet difference in elevation per 100 feet of horizontal distance (the slope in per cent is equal to the difference in elevation divided by the horizontal distance and multiplied by 100).

The following rules indicate the maximum slope on which different sprinkler systems can generally be operated satisfactorily, although there are exceptions to these rules. This data is also included in Table 1 (page 43).

If the land has only slopes of less than five per cent, any type of sprinkler system can be used.

If the land has slopes of approximately five per cent, any type of sprinkler system boom can be used. The long boom has a tendency to tilt over on steeper slopes.

If the land has slopes of approximately five per cent and more, there may be problems with aligning multisprinkler, tractor-moved systems. Side-wheel-roll and side-move systems are also difficult to keep in alignment on the steeper slopes.

Self-propelled center-pivot and side-move systems may not maintain proper alignment on slopes of five to fifteen per cent or more. This depends on the design of the system.

If the land has slopes of fifteen per cent or more, one is limited to the use of hand-moved types; the self-propelled, single sprinkler type; or the permanently installed type. Regardless of the type of system used, erosion becomes more of a hazard on the steeper slopes. Proper conservation measures should be used.

Effect of water intake rate

95. Some systems are better adapted to extreme soil conditions than others. For example, if the soil absorbs water very slowly, a system should be selected that will apply water slowly. Table 1 gives the range of application rates that can be expected from the various sprinkler systems.

96. The water intake rate of the soil and the slope of the field are closely related in the planning of an irrigation system. If the soil absorbs water slowly and the slope is fairly steep, a system should be selected that will apply water at a rate that is low enough to prevent runoff.

97. Single-sprinkler systems using big guns have a tendency to produce large droplets that fall from a considerable height. This is particularly true if the system is operating with water pressures which are too low. The single-sprinkler system may, therefore, not be satisfactory for soil that absorbs water slowly and if the slope is fairly steep.

Effect of shape of area to be irrigated

98. Almost all systems are adaptable to square or rectangularly-shaped fields because of the uniform lengths of the laterals. Self-propelled, side-wheel-roll and side-move systems were, in fact, developed for use on square or rectangularly-shaped fields.

99. If the field is irregularly shaped, there will be no difficulty in using the hand-moved or tractor-moved single sprinkler, the tractor-moved rotating boom, or the permanent type of system. These can be designed to fit almost any shape field. However, it will be difficult to adapt tractor-moved systems to use on an irregularly-shaped field without a

loss of efficiency. Those systems with flexible hose laterals work best when operated from a mainline in the center of a field of uniform width.

100. The center-pivot systems irrigate only circular areas in a field. There will be a loss of about 20 to 25 per cent in the corners of a square-shaped field, unless special provisions are made for irrigating the corners. If the field is rectangular or irregularly shaped, there will be still more area that is not irrigated with this type of system.

Effect of field surface conditions

101. Rough land, with irregular slopes, streams and ditches, presents problems for most types of systems. Hand-moved and permanent systems can be designed to fit such conditions without too much difficulty, but for tractor-moved systems the field must be smooth enough for safe operation of the tractor. Special preparation must be made before a self-propelled system can be installed. Both the self-propelled single sprinkler and the self-propelled boom sprinkler systems need a strip of uncultivated land for the travelling sprinkler. It is best to leave a strip 8 to 12 feet wide for each lateral station.

102. A center-pivot or a self-propelled side-move system must have a reasonably smooth path for the wheels, tracks or skids. If the fields are hilly, flexible couplings can be put in the laterals that will allow them to flex as they travel over high and low areas. Terraced fields can be irrigated with these systems, but the terrace ridges will have to be maintained where the wheels on the sprinkler systems cross them.

Effect of crops grown

103. The crops that can be grown are limited if either a multi-sprinkler hand-moved system or a permanent system is selected. These systems can

be designed for row crops, sod crops, vineyards and orchards. The gun-type single sprinkler systems are safe to use on most crops provided sufficient water pressure is maintained to keep the droplet size small. Otherwise there may be some damage to delicate crops. Some small plants, such as young tomatoes, may be uprooted or buried by large drops of water. Almost any type of system can be used for pasture or sod crops.

104. Multi-sprinkler tractor-moved systems are better adapted for pasture and sod crops than for other crops. This is because the lateral is moved in a zig-zag manner across the field, which would damage a field crop unless a section is left unplanted. For vineyards or orchards, special paths and guides must be made for towing the pipe. If the crops are taller than four feet, a side-wheel-roll system cannot be used because the lateral is too near the ground.

105. The rotating-boom and center-pivot systems are adaptable to almost any crop that does not grow more than 8 or 10 feet high. Center-pivot systems may be used on orchards and vineyards, provided that the tree heights are low and special paths are provided for the wheels.

106 Considerable fogging will result near the center of the center-pivot type of system because of the high water pressure and the smaller nozzles at this point. This fogging and the long length of wetting time may damage some crops in the center area that are sensitive to the wet conditions where fungi can develop. Table 1 (page 43) gives the maximum height for crops that can be grown using different types of sprinkler systems.

Other factors affecting the selection of sprinkler systems

107. There are several other factors which will affect the selection of a sprinkler system. Three of these are the amount of labour required, the acreage which is expected to be irrigated and whether or not the sprinkler systems will be used for other purposes.

108. Table 1 (page 43) shows the approximate amount of labour required per acre of irrigation using the different systems. Hand-moved systems require so much labour that they practically cannot be used except for very small acreages of high-value crops. The current trend is towards using systems that will require the least amount of skilled labour, such as the self-propelled and permanent systems. One reason for this trend is that the skilled labour required for moving the system is not available in many areas. The other reason is that the cost of skilled labour may be too high compared to the financial returns of the irrigation system.

109. The acreage to be irrigated may be a factor in selecting a sprinkler system. Table 1 gives the suggested range of acreages that can be adequately covered by a single system, provided that there is enough water and mainline pipe capacity to deliver the water. The capacity is shown of a single sprinkler and a lateral. All of the sprinkler systems can be increased in size, but is more economical to operate a system within the recommended limits.

110. If it is planned to use the system for other purposes as well, such as crop cooling or frost protection, either a hand-moved solid set or a permanent system must be selected. Sprinklers must be operating almost continuously during the time that the protection is needed. Almost any type of sprinkler system can be adapted to the distribution of pesticides and liquid fertilizers.

111. If it is planned to distribute liquid animal waste with the system, a hand-moved system is not recommended. Most other sprinkler systems can be used for this purpose, however. If there are any solids in the effluent, larger sprinkler nozzles may be necessary. Self-propelled systems driven by water pistons are usually not recommended for use in waste disposal.

Table 1. FACTORS AFFECTING THE SELECTION OF SPRINKLER IRRIGATION SYSTEMS

Type of System	Maximum Slope	Water Application Rate Min.	Water Application Rate Max.	Shape of Field	Field Surface Conditions	Max. Height of Crop	Labor Required	Size of Single System	Approx. Cost*	Cooling and Frost Protect.	Adaptable To: Pesticide Application	Adaptable To: Fertilizer Application	Adaptable To: Liquid Animal Waste Distribution
	(per cent)	(inches per hour)				(feet)	(hrs. per acre per irrigation)	(acres)	(dollars per acre)				
Multi-Sprinkler													
Hand-moved:													
Portable set	20	.10	2.0	Rectangular	No limit		0.50 - 1.50	1 - 40	50 - 200	No			Not Recom.
Solid set	No limit	.05	2.0	Any shape			0.20 - 0.50	1 or more	400 - 900	Yes			
Tractor-moved:					Smooth enough for safe tractor operation	No limit							
Skid-mounted	5 - 10	.10	2.0				0.20 - 0.40	20 - 40	100 - 300				
Wheel-mounted	5 - 10	.10	2.0				0.20 - 0.40	20 - 40	100 - 300				
Self-moved:				Rectangular									
Side-wheel-roll	5 - 10	.10	2.0		Reasonably smooth	4	0.10 - 0.30	20 - 80	100 - 300				
Side-move	5 - 10	.10	2.0			4 - 6	0.10 - 0.30	20 - 80	125 - 300				
Self-propelled:					Clear of obstructions, path for towers								Yes
Center-pivot	5 - 15	.20	1.0	Circular		8 - 10	0.05 - 0.15	40 - 160	125 - 250				
Side-move	5 - 15	.20	1.0	Square or Rectangular		8 - 10	0.05 - 0.15	80 - 160	125 - 250	No	Yes	Yes	
Single-Sprinkler													
Hand-moved	20	.25	2.0	Any shape	No limit		0.50 - 1.50	20 - 40	50 - 200				Not Recom.
Tractor-moved:					Safe operation of tractor								
Skid-mounted	5 - 15	.25	2.0				0.20 - 0.40	20 - 40	100 - 300				
Wheel-mounted	5 - 15	.25	2.0			No limit	0.20 - 0.40	20 - 40	100 - 300				
Self-propelled	No limit	.25	1.0	Rectangular	Lane for winch and hose		0.10 - 0.30	40 - 100	120 - 250				
Boom-Sprinkler													
Tractor-moved	5	.25	1.0	Any Shape	Safe operation of tractor	8 - 10	0.20 - 0.50	20 - 40	200 - 300				Yes
Self-propelled	5	.25	1.0	Rectangular	Lane for boom and hose	8 - 10	0.10 - 0.50	40 - 100	200 - 300				
Permanent													
Manual or Automatic	No limit	.05	2.0	Any shape	No limit	No limit	0.05 - 0.10	1 or more	400 - 1000	Yes			

*Does not include the cost of water supply, pump, power unit and mainline

IV. CRITERIA TO BE CONSIDERED IN PURCHASING IRRIGATION SYSTEMS

112. For many centuries, all irrigation systems were gravity systems where water was discharged from a ditch or pipe to the head of a field and water flowed by gravity down the length of the field. Factors such as water supply, soil type, field slope, crop etc., were considered in designing the system. In recent decades, sprinkler and drip systems have been introduced and design has become somewhat more complicated, but many of the same factors that were considered many centuries ago must still be considered in design and selection of irrigation systems today.

The factors that should be considered are:

- Water supply
- Soil type
- Crop
- Topography
- Field size and shape
- Labour
- Need for environmental modification
- Rainfall distribution
- Financial resources
- Lease versus purchase
- Dealer availability and service.

The order in which these factors are considered is not necessarily in the order given, but each should be considered.

113. The most important factor is the water supply. The system is of no value unless there is water available. To apply one inch of effective irrigation to one acre of land requires between 33,000 and 37,000 gallons of water. Water sources include impounded ponds, dug pits, streams and wells. The source of water is not too important provided sufficient water is available to meet the needs of the crops. Many ponds and irrigation pits are supplied by surface runoff and have little or no recharge. These must store enough water to meet crop needs during the irrigation season. Stream flow will be less during drought periods. Wells will provide a relatively constant

supply throughout the year. Ground water resources may vary greatly and in many areas satisfactory irrigation wells cannot be developed. Well drillers and water resource officials can provide data on ground water availability. Some growers are now going to combination water sources, a pond which is partially recharged by a well. Where the irrigation system is not operated continuously, the well capacity can be reduced, resulting in a lower well cost. The cost of a combination water supply system requiring two pumps and power units must be compared to the cost of a single water source and one pump and power unit. In many areas, adequate ground water may not be available to operate an irrigation system, but adequate water supplies may be obtained by combining surface storage and ground water.

114. Water supplies need to be developed in the off-irrigation season. Contractors may not be as busy during this time and can better schedule their work and can possibly reduce their costs. Normally, well construction costs will be lower if the contractor is not required to guarantee a certain pumping rate. Test wells can provide good data on potential yield from wells and are a good investment.

115. Soil type is important for several reasons. Water application rates, total amount of water to be applied at one irrigation and frequency of irrigation is affected by soil type. In fields that have more than one soil type, the system must be designed for the major soil type. Normally, sandy soils will have a higher intake rate, a lower water holding capacity, and will require more frequent irrigation than will clay soils.

116. The crop to be irrigated will play a major role in the profitability of irrigation. Some crops, such as tobacco, soybeans, peanuts and hay crops, have the potential to recover from short drought periods with minimal reduction in yield or quality. Other crops, such as corn and most of the short season horticultural crops, are drastically affected by droughts at the pollination and fruit development stage of growth. The yield response of some

crops to irrigation may not be sufficient to return a profit after substracting the cost of owning and operating an irrigation system. The soil type on which crops are grown and the rainfall distribution can affect the profitability of irrigation.

117. Most countries have available information on historical rainfall distribution. Some countries have published information on probability of drought days and average rainfall amounts. A potential irrigator should study these data to determine the extent of drought in his area. There is considerable variation in rainfall. Localized rainfall distribution may vary considerably from published data.

118. Once it has been determined that an adequate water supply is available or can be obtained and that it may be profitable to irrigate, one can then begin to decide on what type of irrigation system will best fit a particular situation. There are a number of people who can provide assistance. The Agricultural Extension Services and the Soil Conservation Services in developing countries should have personnel who are specialized in irrigation. Consultants may be employed to provide design assistance. Irrigation dealers provide assistance on system selection, design and operation. It is recommended that several irrigation dealers be contacted.

119. There is a wide choice of irrigation systems from which to select. They are not all equally adaptable to a particular situation. Even though there are a number of types of irrigation systems, for most growers the choice is limited either because of initial cost per acre, topography, field size and shape, crop, soil type, acres to be irrigated, labour available, or whether the system will be used for purposes other than supplying soil moisture.

120. Purchasing an irrigation system means the purchase of a variety of components to complete a system. These components are provided by several manufacturers and it is up to the dealer or a consultant to ensure that all the components fit together to provide a system that will meet the requirements, namely to meet the peak moisture demands of the crop to be irrigated.

V. IMPLEMENTATION OF IRRIGATION PROJECTS IN DEVELOPING COUNTRIES

121. When sprinkler systems are being constructed, it is important to take account of the farming conditions in which a particular system will operate.

Homogeneous cultivation

122. When constructing a sprinkling system for homogeneous cultivation, larger pieces of ground can be combined into sprinkling units. In addition, centralized management makes it possible for sprinkling to be more easily controlled.

123. Division of sprinkling areas into plots for different farmers. In order to calculate to cost of this method of sprinkling, it is essential to measure accurately the amount of water which will be used. In addition, suitable supply equipment is required to limit the water supply to individual plots of land; thus it is possible to guarantee uniformity in the amount of water supplied throughout the whole irrigation project.

124. It is absolutely essential to control the operation of the sprinkler in keeping with the hydraulic conditions in the water supply network. The advantage of the above sprinkling systems is that they have a central water supply. The investment outlay for the supply network as well as for the pumping station is apportioned on the strength of plot sizes. The use of larger pumping stations makes automatic control with optimal monitoring possible.

125. Small systems in scattered areas, each with separate water supplies. These systems must be supervised by their respective owners. However, they do have the advantage of being more flexible, e.g. they can be used when crop rotation takes place and when the location of cultivation is changed.

The basic requirements for sprinkler projects

126. In order to construct sprinkler projects, it is essential to possess accurate knowledge of soil and climatic conditions. Because the installation of a sprinkler constitutes quite a considerable investment, the conditions in which crops are grown, possible yield increases, rise in incomes etc. must be assessed so that the efficiency of these projects can be guaranteed.

127. Similarly, sprinkler technology must be chosen according to the conditions in which it will be employed. The following conditions must be taken into consideration:

- Small or large plots
- Difference in height between the sprinkled areas
- Existing kinds of cultivation such as field or permanent cultivation
- Method of farming.

128. The standard sprinkler system, Solid Set System and the hose Pull System, have proved to be extremely good value when used on small plots of land. These systems offer the following advantages:

- The sprinkling equipment only rotates on one owner's plot. Careful treatment is, therefore, guaranteed.
- It is a very economical investment and can be used universally for all types of cultivation.
- Easily adaptable to sections of land which have to be sprinkled to a greater or lesser extent.
- Accurate measurement of water supply.

129. Mechanized sprinkler systems such as the pivot or linear systems, can only be used economically on larger plots of land. Therefore, they cannot be used so extensively on small plots.

130. Mechanized sprinkler systems require adequate maintenance and servicing. If maintenance is not carried out satisfactorily the entire machine will break down, i.e. it will not be possible to sprinkle larger units of land. In the case of standard sprinkler systems, breakdown is restricted to small units, e.g. a small sprinkler. Therefore, sprinkling of most of the land can still be maintained. Especially if only inadequate servicing is available, then these systems are substantialy more reliable in the long term.

131. In order to operate sprinkling systems, it is essential to make sure that appropriate maintenance and servicing can be carried out. For large systems, this takes place in central workshops. Centralized servicing should also be aspired to in the case of systems with several owners.

132. The financing of both of the systems mentioned here must be effected according to statutory requirements. For systems shared by a lot of owners, an appropriate kind of co-operative is usually created to unify procedures.

133. Small- and medium-scale enterprises have the advantage of multipurpose methods of farming which can more easily respond to market demands. Furthermore, most of the time less bureaucracy is needed because it is easier to keep these sprinkling systems under surveillance.

VI. MANUFACTURING OF IRRIGATION COMPONENTS AND EQUIPMENT IN DEVELOPING COUNTRIES

Definition of irrigation equipment and components

134. The various components and elements of the different irrigation systems from water supply source to the plants might be defined as follows:

(a) **Pump station**
- Electro motors
- Diesel motors
- Pumps such as deep-well pumps, centrifugal pumps, submersible pumps etc.
- Accessories such as non-return valves, stop valves, pressure regulators etc.

(b) **Main distribution system**
- Channels
- Pipes (100 to 2,000 mm in diameter) and fittings made of
  - steel
  - asbestos-cement
  - plastics
- Accessories and hydrants

(c) **Irrigation systems**
- Surface irrigation or traditional systems
  - channels with float gates
  - furrows
  - gated pipes
  - hose (for siph n tubing)
- Sprinkler systems
  - Galvanized steel or aluminium pipes (50 to 200 mm in diameter of quick-coupling type)
  - Sprinklers
  - Continuously move mechanized irrigation systems
    - o travelling machines
    - o center pivot
    - o lateral move systems
  - Drip irrigation system
    - o larger filter system
    - o plastic pipes (13 to 25 mm in diameter) and fittings
    - o emitters.

135. The average proportion of costs of the main components of various irrigation systems are given in the following table to make apparent the importance of each component with regard to the irrigation system adopted.

Table 2. **Proportion of Cost of the Main Components of Various Irrigation Systems (in per cent)**

	Pump Station	Main Distribution System	Irrigation System or Irrigation Lateral
Sprinkler systems	25	50	25
Travelling machine	20	35	45
Center pivot	10	15	75
Drip irrigations	30	20	50

136. A smooth operation of any irrigation system requires systematic maintenance, repair and replacement (after elapsing of the useful life of the components). The following Table 3. spells out the details on the above factors.

Local conditions and their impact on the development of manufacturing facilities for irrigation equipment

137. Although in recent years the importance of irrigation in humid environments has been fully recognized and is being employed, the environmental conditions for determining the extent of irrigation used in agricultural production are governing factors. The influence of local conditions on the irrigation method, and consequently the required components, is spelled out in Part I of the present document.

138. These local conditions are the governing factors for determining the potential demand of the appropriate irrigation systems and consequently the needs for irrigation components in any market. Depending on the local conditions, the demand for various irrigation components from one country to another will be different. Therefore, the required manufacturing facilities and the degree of manufacturing complexity needed might also be different.

Table 3. Suggested Depreciation Period and Annual Maintenance Cost for Components of an Irrigation System

Component	Depreciation (hours)	Period (yr)	Annual Maintenance and repairs (% of initial cost)
Pumping plant			
structure	-	20-40	0.5 - 1.5
Pump, vertical turbine			
bowls	16000-20000	8-10	5 - 7
columns, etc.	32000-40000	16-20	3 - 5
Wells and casings	-	20-30	0.5 - 1.5
Pump, centrifugal	32999-50000	16-25	3 - 5
Power transmission			
gear head	30000-36000		5 - 7
V-belt	6000	3	5 - 7
flat belt, rubber/fabric	10000	5	5 - 7
flat belt, leather	20000	10	5 - 7
Prime movers			
electric motor	50000-70000	25-35	1.5 - 2.5
diesel engine	28000	14	5 - 8
gasoline engine			
air cooled	8000	4	6 - 9
water cooled	18000	9	5 - 8
propane engine	28000	14	4 - 7
Open farm ditches (permanent)		20-25	1 - 2
Concrete structures		20-24	0.5 - 1.0
Pipe, asbestos-cement and PVC (buried)		40	0.25 - 0.75
Pipe, aluminium, gated surface		10-12	1.5 - 2.5
Pipe, steel waterworks class (buried)		40	0.25 - 0.50
Pipe, steel coated and lined (buried)		40	0.25 - 0.50
Pipe, steel coated, buried		20-25	0.50 - 0.75
Pipe, steel coated, surface		10-20	1.5 - 2.5
Pipe, steel galvanized, surface		15	1.0 - 2.0
Pipe, steel, coated and lined (surface)		20-25	1.0 - 2.0
Pipe, wood, buried		20	0.75 - 1.25
Pipe, aluminium, sprinkler use (surface)		15	1.5 - 2.5
Pipe, reinforced plastic mortar (buried)		40	0.25 - 0.50
Pipe, plastic, trickle, surface		10	1.5 - 2.5
Sprinkler heads		8	5 - 8
Trickle emitters		8	5 - 8
Trickle filters		12-15	6 - 9
Mechanical move sprinklers		11-16	5 - 8
Continuously moving sprinklers		10-15	5 - 8

Source: Design and Operation of Farm Irrigation Systems;
The American Society of Agricultural Engineers, December 1980.

139. The existence of a market demand can be considered as a pre-requisite for establishing any production facilities. In this connection, a distinction should be made between potential demand and effective market demand. In our particular case, the difference can be considerable. In spite of the existence of a market potential, the effective market demand is dependent on:

- Agricultural structure in the country; size of land; etc.
- Educational background of the farmers
- Purchasing power of the farmers
- Governmental policies and financial supports
- Price structure of crops, water, utilities, etc.
- Others

140. By having the above viewpoints in mind, for the assessment of possibilities of manufacturing of irrigation equipment in developing countries, the following domestic and regional conditions must be taken into account:

141. Existence of a domestic market demand to justify the local production. As mentioned above, the effective demand is governed by environmental conditions, macro-economic situation in the concerned country as well as micro-economics of the agricultural sector. The demand should preferably surpass the economic scale of manufacturing to achieve better financial viability. Also the following conditions should be fulfilled:

Existence of feeding industries
Techno- and socio-infrastructure
Availability of skilled labour force
Availability of financial means.

142. However, it should be emphasized again that the main criterium is the availability of demand while the other conditions mentioned above can be provided or arrangements made for.

143. Due to different environmental conditions prevailing in different developing countries (arid countries in comparison to humid countries), different irrigation systems and consequently different components are needed. Therefore, in each particular case, the demand for the most important components must be taken into account for assessment of their manufacturing possibilities.

144. As the various irrigation components are of different manufacturing complexity, their economies of scale of manufacturing are different. However, all local conditions, such as technical infrastructure, possibilities of interlinkages, existence of feeding industries, price structures, selected degree of integration etc. have an impact on the economic scale of manufacturing. Therefore, in each particular case, by investigating all factors the right decision on manufacture or purchase must be made.

145. The local conditions and, consequently, the market structure and the availability of techno-infrastructure, are the determining factors for any decision with regard to the degree of integration and local integration (local content).

146. By taking into account all of the local conditions, an optimal degree of integration (local content) for various irrigation components in each developing country must be selected. The market demand and the level of technical skills and possibilities of interlinkages with other industrial sectors have considerable impact on the optimal degree of integration (local content), i.e. on decisions regarding self-manufacturing or buying from outside sources (purchased components); there is no general guideline for determining the degree of integration for the manufacture of irrigation components in all developing countries and in each particular case, in-depth investigations and studies are required to select the optimal solution for the key components which might vary from country to country due to changes in local conditions.

147. For the selection of an optimum degree of integration (local content), the existing techno-infrastructure and the local economy must also be taken into account and a proper strategy with regard to local integration must be worked out.

Selection of manufacturing technologies

148. **Brief description of various irrigation components' manufacturing technologies.** The various irrigation components and equipment are defined in para 134. By taking into account the existing irrigation practices in the developing countries, the irrigation components can be classified into the following groups:

- Pumps
- Various pipes (steel, aluminium, asbestos-cement, plastic)
- Fittings and accessories
- Diesel engines
- Electro motors
- Sprinklers
- Quick-coupling pipes (steel, aluminium)
- Mechanized irrigation systems
- Drip irrigation systems.

The technologies involved for manufacture of the most important components, i.e. pumps, pipes and modern irrigation components, are dealt with in the following sections:

Manufacture of pumps

149. The main types of pumps usually used in irrigation schemes are as follows:

150. **Centrifugal pumps.** These pumps are driven by electro-motors or diesel engines and are of limited suction capacity. Therefore, they are usually used in surface water pumpage and are of limited draw-off.

151. **Deepwell pumps.** These pumps are mainly used for pumpage of underground water. The drive unit is located at ground level while the pumping unit is placed under water in the well. A pipe connects these two units which carries the water and house the connection cardan shaft between driving and pumping units.

152. **Submersible pumps.** These pumps are driven only with electro-motors. The driving unit as well as pumping unit is under water. These pumps are used when the draw-off needed exceeds the depth which normal centrifugal pumps can suck.

153. The pumps are of single or multi-stage performance depending on the pressure requirements. The main components of the above mentioned pumps are:

- Casing; made of cast iron
- Impeller; made of cast iron, plastics or non-ferrous alloys (bronze)
- Crankshaft; made usually of alloyed steel
- Accessories such as anti-friction bearings, pressure gauge, sealings, stuffing box, nuts and bolts, etc.

154. For the manufacture of the above mentioned components different processes and technologies are needed, i.e.:

- Various casting methods are used for the manufacture of casings and impellers from cast iron or non-ferrous alloys respectively

- Crankshafts are made of alloyed steel and are finished by employing various machining operations

- For the manufacture of accessories different technologies and processes are used and are usually manufactured in specialized facilities. Therefore, most of the pump manufacturers buy these components from outside sources. A good example is anti-friction bearings which are produced by companies which are specialized only in producing all kinds of bearings.

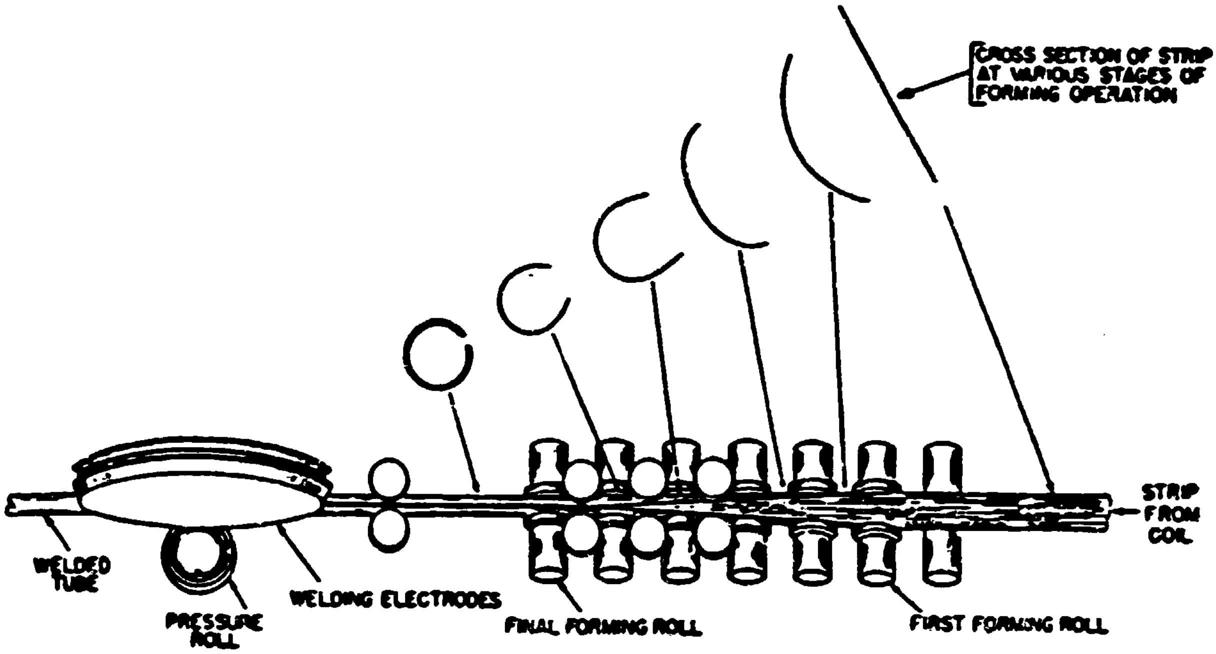
155. The important international pump manufacturers are producing a large variety of pumps for all purposes and are specialized only in pumps production. In this connection, in the developing countries, pump production facilities should also be planned by taking into account the requirements of other sectors of market to benefit from mass production and be able to rationalize the cost.

Manufacture of pipes

156. Steel pipe. Many methods and different types of equipment are involved in pipe production. Briefly, pipes may be categorized as welded (that is, exhibiting a seam) and seamless. The former may be fabricated by heating and forming flat strip or skelp into a tubular form and lap- or butt-welding the joint. Alternately, the strip, when cold may be formed into a tubular shape and the seam electrically welded by resistance heating at low or high frequencies or by submerged arc welding. The important steel pipe manufacturing process which is usually used for production of pipes for irrigation purposes is Electric-Resistance-Welding (E.R.W.) process.

157. Electric-Resistance-Welded Tubing. Tubing up to about 26 inches in diameter with wall thicknesses up to 0.5 inch is manufactured by the E.R.W. method. The basic steps involved in the E.R.W. process are: slitting (when multiple-width strip is used), forming, welding, sizing, cutting and finishing. The forming of the strip is illustrated by Figure 13 (page 61). The coils are either fed directly into forming rolls or into a looper to permit the end-to-end welding of strips. The strip first passes through an edge trimmer where the width is established and the edges made suitable for welding. It then passes sequentially through breakdown or forming rolls, idler vertical closing rolls and finpass rolls. The welding is accomplished by restraining the tube on squeeze rolls and heating the edges by low-frequency current applied through electrode wheels or by radio-frequency currents applied inductively or by sliding contacts.

Figure 13. The Conversion of Strip into a Resistance-Welded Tube



After welding, the flash is removed and the tube subjected to any post-welding treatments that may be required metallurgically. Then, after cooling, the pipe is processed on a sizing mill (usually consisting of several driven horizontal rolls and several idler vertical rolls) and cut to length.

158. Aluminium pipe is made by three processes:

- drawn seamless pipe
- seamless extruded pipe and
- welded pipe.

159. The drawn seamless tubing is made by drawing tube stock produced by die and mandrel extrusion methods. It is drawn through a die to produce final dimensions.

160. The seamless extruded pipe is produced from hollow extrusion ingot and is extruded by the use of the die and mandrel method or cold-drawn. The ingot used is cast in hollow form, or cast in solid form and drilled or pierced from a solid ingot. The welded pipe is made by welding the edges of a formed sheet of aluminium.

161. Aluminium pipe can be protected from some corrosive factors by cladding. This is a pipe composed of an aluminium alloy core having the inside or outside surface or both metallurgically bonded with an aluminium alloy coating that is anodic to the core, thus protecting the core against corrosion by electrolysis.

162. The pipe sizes and pipe wall thicknesses required (relatively thin wall) for quick coupling aluminium pipes in sprinkler irrigation systems are best manufactured by the welding process which is also the most economic process.

163. Plastic pipe is a man-made organic polymer. There are numerous kinds of plastics, but four major kinds are used in pipe manufacture. These are:

- Polyvinyl chloride (PVC)
- Polyethyiene (PE)
- Acrylonitrile-butadiene-stryrene (ABS)
- Polybutylene (PB).

Of these, only polyvinyl chloride (PVC), polyethylene (PE) and acrylontrile-butadiene-styrene (ABS) are presently used to any great extent in sprinkler irrigation.

164. Plastic pipe is manufactured by the extrusion process, converting raw thermoplastics (PE, PVC, PB, ABS) granular or powdered material to continuous lengths of finished product. A single- or multiple-screw extruder accepts the raw material from a feed source, subjects the material to heat and pressure for complete melting and mixing, then forces the melted material continuously through extrusion dies to shape the pipe, which is then cooled to set the shape, and cut to length by haul-off and cutting units.

165. Asbestos-cement pipe was first developed in Europe, where it was used to carry sea water for fire fighting and street cleaning purposes. This type of pipe has been manufactured in Great Britain since 1928 and is used in many countries around the world.

166. The pipe is composed of an intimate mixture of Portland cement, Portland blast furnace slag cement, and clean asbestos fibre with or without silica. This mixture is formed under pressure on a mandrel to provide a dense, homogeneous pipe with a smooth interior surface. The mixture of cement and asbestos fibre should not contain grit, organic fibre, or other adulterants. The finished pipe may be cut, drilled and tapped.

167. Asbestos-cement pipe is made in classes of 100, 150 and 200. These class numbers indicate working pressures in pounds per square inch (689, 1034 and 1378 kilo-pascals). It is manufactured in sizes ranging from 3 to 36 inches (76.2 to 914.4 mm) inner diameter and in standard 13 foot (4 m) lengths.

Fittings and accessories parts

168. For the production of fittings, couplings and all other mechanical parts, the standard workshop methods such as:

- cutting
- forming
- pressing
- various machining work
- welding
- casting
- etc.

are required. Finally the various manufactured parts have to be assembled to the finished products such as riser, tee, valves, etc.

Diesel engines and electro-motors

169. Diesel engines and electro-motors are used in a large variety of applications and their economic production must be accomplished by taking into account all possible uses and the benefits of mass production. Furthermore, the manufacture of these components is a very specialized field and cannot be mixed with another specialized manufacturing field like the manufacture of irrigation components. Therefore, the production of these components is not recommended within the framework of irrigation equipment manufacturing but by taking into account all end-users in the agricultural sector as well as industrial sectors.

Sprinklers

170. A sprinkler is composed of a variety of small components most of which are made of non-ferrous metals. The choice of metal for each part is based on its suitability and its market prices. The nozzle is made of plastic. Different casting methods are usually used for the production of various metallic parts. The production of plastic nozzles is carried out by the injection molding method. See also the following process diagram Figure 14 (page 66).

Quick-coupling pipes

171. The manufacture of pipes is as described in the preceding sections. The manufacture of couplings and their assembly requires standard workshop operations such as material shearing, forming by pressing, welding etc. A simplified process diagram is shown in Figure 15 (page 67).

Mechanized irrigation systems

172. The manufacturing process of the mechanized irrigation systems can be groupes into the following standard workshop activities:

- Material cut-to-length
- Metal cutting (machining) works
- Manufacturing of various components and assembly lines.

Figures 16 (page 68) and 17 (page 69) show manufacturing processes of travelling machines and center pivot systems respectively.

Drip irrigation components

173. A simplified process diagram for the production of drip irrigation components are given in Figure 18 (page 70). As can be seen from this figure, two production lines are necessary, viz:

- Extrusion line for production of pipes
- Injection moulding facilites for manufacture of fittings and emitters, nozzles etc.

Remarks regarding choice of manufacturing

174. From the brief description of manufacturing technologies of the various irrigation components given in the preceding section, it becomes evident that the complexity of technologies involved varies in quite a wide range. It is of benefit for developing countries to start manufacturing the simpler and more common components. By mastering of the technologies involved, new production facilities for other more complicated products can then be implemented.

Figure 14. Sprinkler Manufacturing

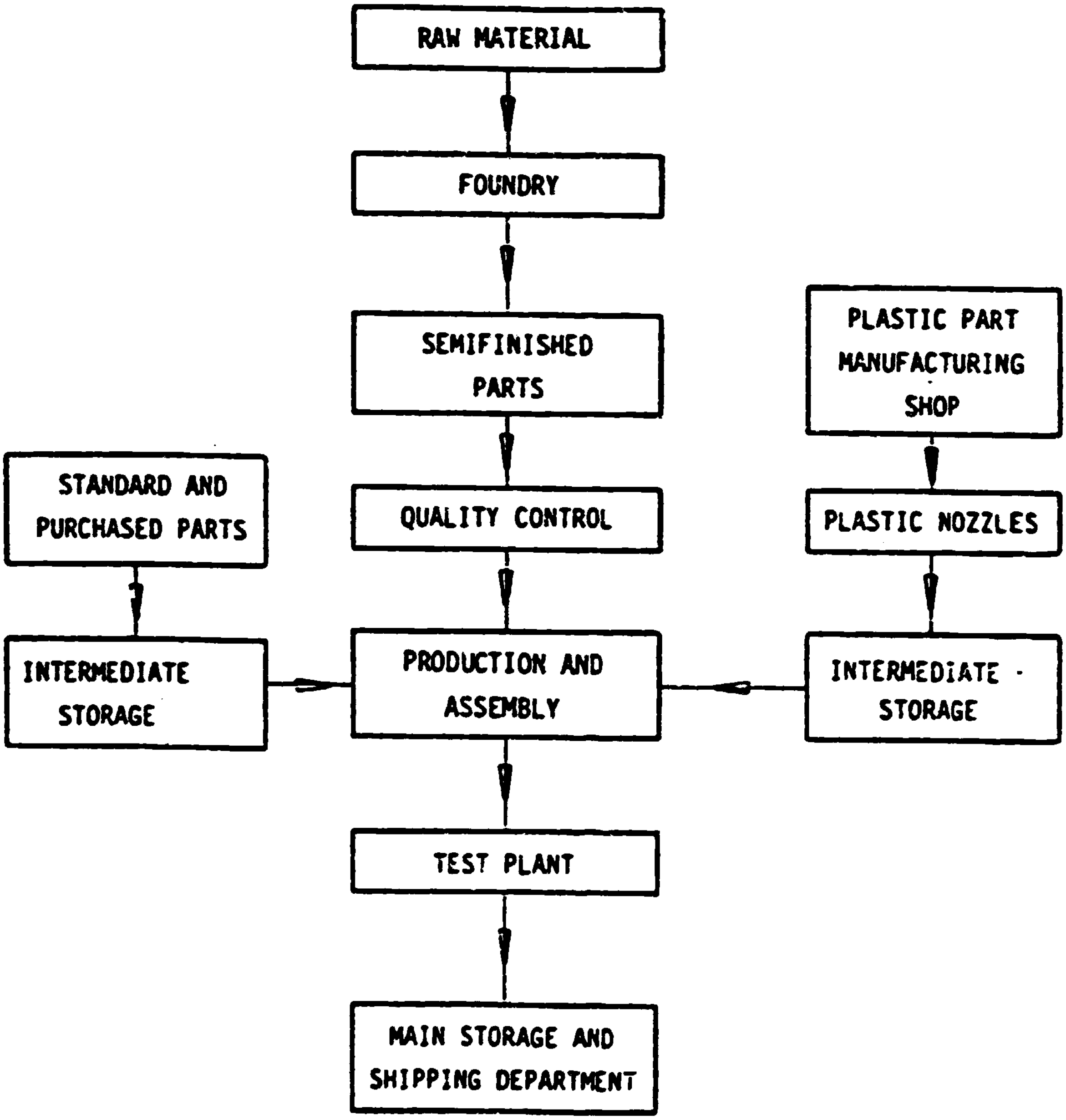


Figure 15. Couplings and Fittings Manufacturing (Steel and Aluminium)

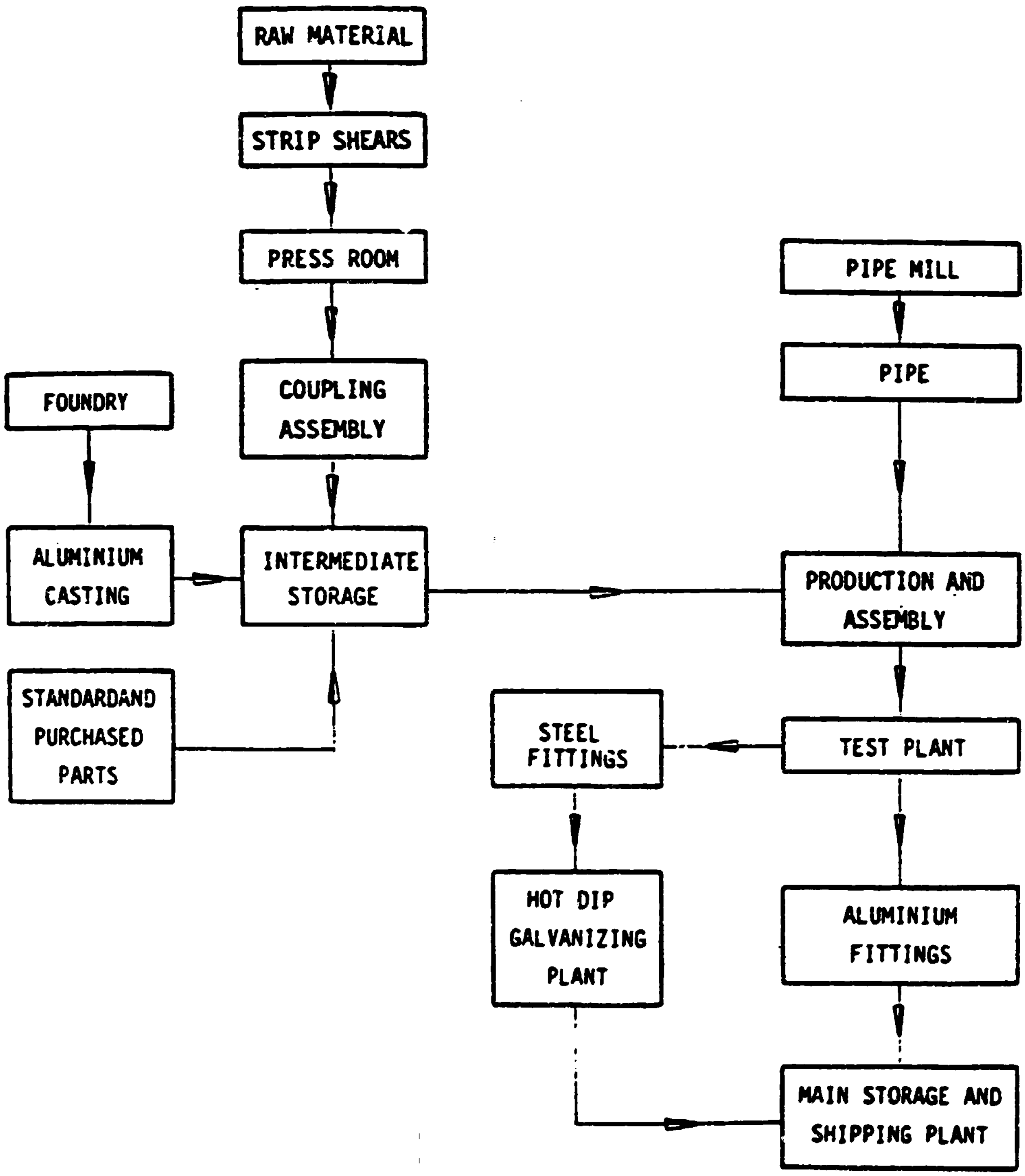


Figure 16. Travelling Gun Irrigator Manufacturing

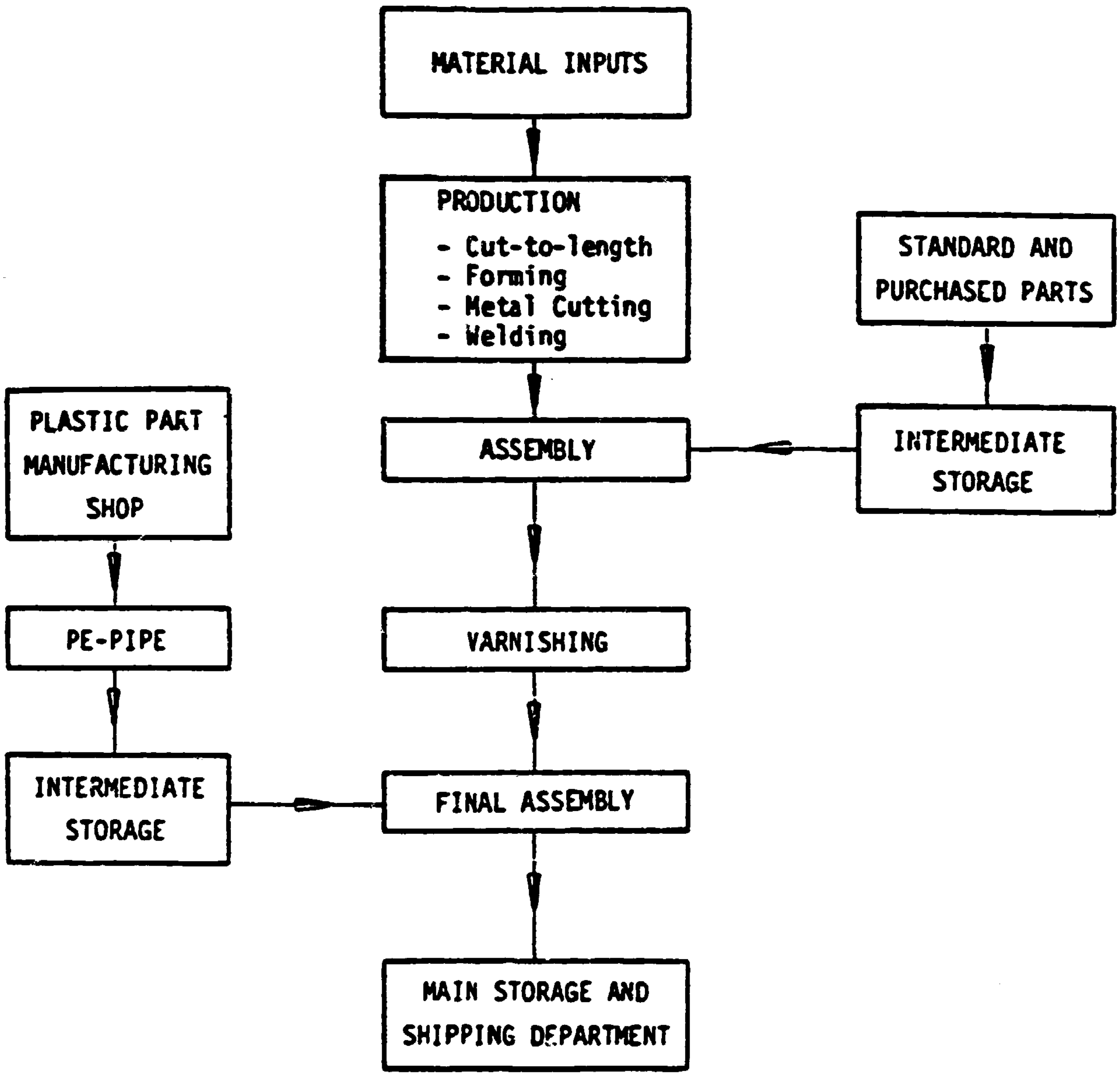


Figure 17. Center Pivot Manufacturing

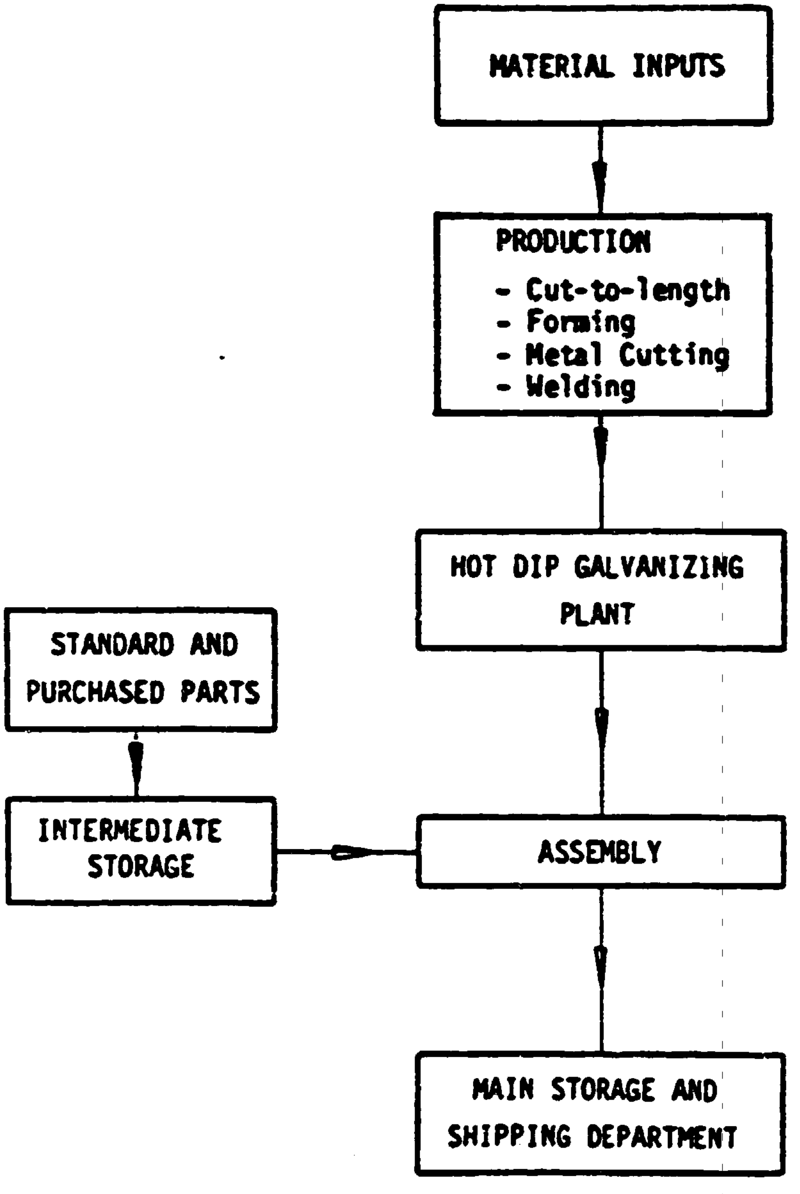
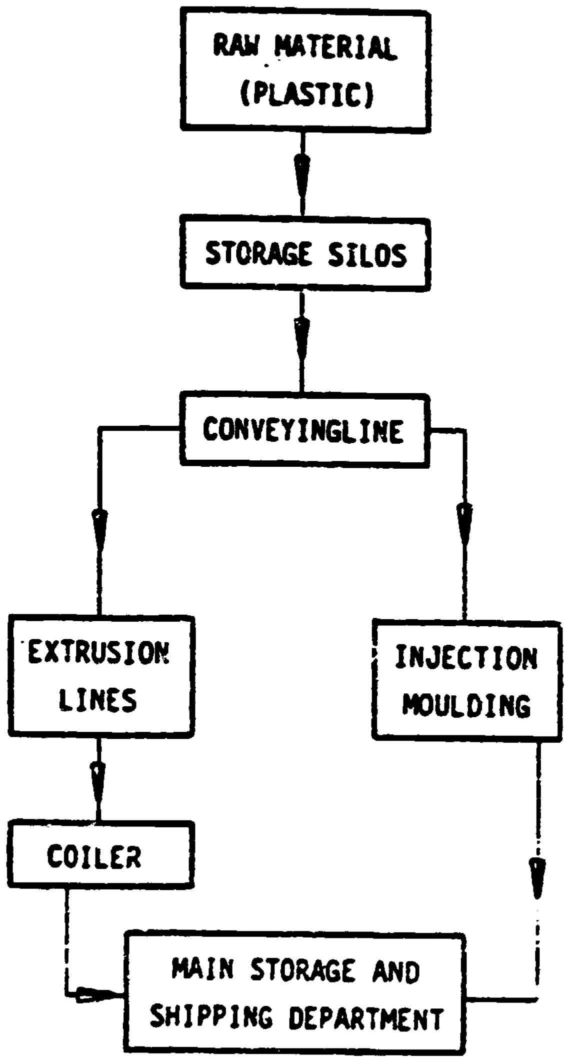


Figure 18. Drip Irrigation and Plastic Parts Manufacturing



175. A related issue is that for the manufacture of simpler components, much higher local content (degree of integration) could be achieved due to lesser numbers of parts or elements involved. Therefore, less dependency on purchased components and importation from developed countries.

176. By taking into account the above viewpoint the following irrigation components seem to be suitable for manufacture in developing countries:

- Quick-coupling pipes
- Pipe fittings and accessories
- Sprinklers

177. For the manufacture of the above components, a local content of more than 60 to 90 per cent could be achieved which is a favourable factor for developing countries. The range of 60 to 90 per cent of local content is dependent on the availability of metal producing industries such as steel and aluminium industries in the host country.

178. The above mentioned irrigation components constitute the main elements of the irrigation lateral of pipe sprinkler systems.

179. By having the above components at disposal, modern irrigation of a large variety of lands in developing countries is possible which could play a major role in the increase of agricultural production and consequently food supply security.

180. By manufacturing the suggested quick-coupling pipes and sprinklers, the installation of simple hand move irrigation systems (portable) to fully mechanized solid set is possible.

181. As mentioned in the preceding section, for the manufacture of quick-coupling pipes, a pipe mill and workshop facilities for the manufacture of coupling and fittings are necessary. For sprinkler production, casting facilities together with machine tools for finishing the parts are required (see Figures 14 and 15).

182. Know-how and technological skills for the above mentioned workshop operations are readily available in most of the developing countries; only specific know-how for production of quick-coupling pipes and sprinklers is necessary which could be acquired easily from the international suppliers of reputable makes and designs.

Maintenance strategy

183. Preventive maintenance and proper repair of the machinery is of vital importance. Maintenance is often not given enough attention in developing countries which frequently causes major breakdowns and long production interruptions. Thus, the company should choose a well programmed maintenance policy and maintenance procedures from the beginning of operation.

184. Maintenance strategy should be well suited to the local conditions of the region where the plant is located. If the plant is located in an area with adequate local engineering skills, a good balance of outside contracted maintenance and repair work to in-plant maintenance being done by the own personnel should be found. A good balance of outside and inside repair and maintenance work will facilitate a minimal maintenance cost without jeopardizing the operation. However, the increase of the rate of outside contracting results in the decrease of the rate of availability of the production lines. This is due to the fact that with any breakdown of the production lines which cannot be fixed by own personnel, longer downtimes (repair, waiting etc.) should be taken into account. Thus the production target might not be achieved. Therefore, by taking into account all of the above mentioned aspects, a well balanced and appropriate maintenance strategy should be selected. The appropriate maintenance strategy could be selected when a thorough knowledge of local engineering capacity is at disposal.

Infrastructure and linkages with the rest of economy

185. Economic and technical infrastructure are vital to the development of any capital goods industry. Efficient and economical means of transport, especially for the transport of voluminous finished products to the market, communications, water and energy supply, social infrastructure etc., all are important factors.

186. Basic technical services such as casting, merchant hot-dip galvanizing, manufacture of jigs and fixtures, etc. constitute the technical infrastructure which facilitate the smooth development of the irrigation equipment manufacturing.

187. Supply of raw materials and intermediate goods can also play an important role. Of prime importance is the availability of iron and steel products. In the case of pipe and pumps and even other important irrigation components, iron and steel constitute the major portion of weight and are a major cost element.

188. The manufacture of the main components of irrigation can be classified as low volume high components manufacturing processes. Therefore, ideally can be integrated into a local economy to increase the utilization rate and consequently achieve better economic, i.e. higher local content; e.g. the existence of an engineering or casting industry will positively influence the possibilities of establishing a pump manufacturing unit.

189. On the other hand, the implementation of pumps or pipe production facilities could be of greater importance for the development of other sectors of economy, such as urban water supply and distribution systems etc. In this connection, it can be stated that the impact of the establishment of manufacturing of irrigation components on local economy and infrastructure is double-fold, i.e. the irrigation equipment manufacturing could be integrated in an existing local economy and simultaneously the possible interlinkages with other industrial sectors could be utilized to achieve better economics.

Role of multi-purpose plants as links among the manufacture of irrigation equipment, agricultural machinery and water-related common-purpose capital goods

190. The level of technological complexity of irrigation components run over a wide range and it should be borne in mind that complexity level is dependent upon the selected degree of integration as well as the technological route adopted, i.e. the technological complexity level can be reduced by decreasing the rate of integration, in-plant production, or by simplifying the product design and/or manufacturing processes, or increased by complicating these parameters.

191. From the above statement, it becomes evident that the manufacture of most of the irrigation components requires rather specialized facilities because often different technologies of different complexities are used. It is also of importance to note that the multi-purpose facilities should only be considered if the demand for creation of specialized facilities is not available. However, multi-purpose production should be planned and implemented as an entry route into the irrigation components manufacturing sector. The multi-purpose plant should be considered as a development pole which, in time, hands the manufacture of the products over to new specialized units. The increase of the market demand and the mastery of the technologies within the multi-purpose unit form the basis for these possibilities.

192. For establishment of multi-purpose facilities, the governmental support might be necessary to protect the industry from very large-scale and fully automated international suppliers which have rationalized the cost and can offer the product cheaper on the market.

193. It should also be noted that the multi-purpose facilities must be planned by taking into account that the various products manufactured must have some common dominant characteristics, in which context the nature of the production equipment is not the sole factor to be taken into consideration.

194. Therefore, the multi-purpose facilities can be suggested as under:

- Production facilities for pipes and fittings, for all purposes, such as irrigation, water supply and distribution, etc.

- Multi-purpose facilities for pumps, valves and light agricultural equipment such as rice hullers, dryers, threshers, power tillers etc. In these facilities, production of mechanized irrigation systems could also be planned.

195. The two above mentioned facilities which use completely different production technologies can be also integrated in one multi-purpose plant of course in different shops.

196. On the other hand, the existing multi-purpose plant for manufacture of capital goods, in any developing country, could be adapted for production of irrigation components. This possibility should also be taken into consideration. This can be achieved by detailed planning and implementation of the necessary unit adaption measures and the acquisition of production know-how. In this connection, the adaption of steel pipe production, for manufacturing of quick-coupling pipes (irrigation pipe) and addition of pump production to existing light agricultural machinery production facilities and purchasing of all required casting products can be mentioned as typical examples.

<u>Role of small and medium-scale enterprises in technology transfers, training and financing</u>

197. The small and medium enterprises in comparison to large companies have the following advantages:

- Can respond more flexibly to market opportunities
- Are technically more daring and innovative and
- Tend to rely less on in-plant operations and more on sub-contracting which facilitates more integration into the local economy.

198. Therefore, the small and medium-scale enterprises could play a major role in all aspects of:

- Technology transfer
- Training
- Financing

199. **Technology transfer.** Any kind of technology transfer from joint venture to purchase outright of technology and know-how could be undertaken by these companies. This is due to the fact that they are more flexible in negotiating and the decision in each case could be made more rapidly and without too many internal regulations and constraints. This is true for both sides, i.e. technology suppliers as well as technology purchasers.

200. **Training.** Training is considered as the vital element of survival in the present time. Familiarisation with the technology takes time; a lot of planning is necessary and inevitably long periods of training are needed. Even in western countries where industrialization has become highly sophisticated, the learning processes involved have been grossly under-estimated by users and training is often considered only as an afterthought. International transfer of manufacturing technology is growing. Faced with their inherent problems of high rural populations and scarce resources of highly educated manpower, entrants from developing countries should give training its proper significance. Broader training packages will be required for countries in early stages of development.

201. Micro level skills are required for the establishment of specific industries (e.g. irrigation equipment manufacturing). Training of such personnel goes far beyond formal education. There is much on-the-job training of engineers and production labour. The skills that are developed and passed on in on-the-job or plant specific training, constitute a large fraction of the technology mastered by the manufacturing company. Therefore, it is advisable to acquire the know-how and technology and accomplishment of technical training from a single supplier.

202. In this connection, there are a large number of medium-scale companies, some of them specialized firms in training, which can play a major role in providing training programmes for developing countries for each special field.

203. At the same time, the medium and small-scale enterprises in the developing countries, which are desiring to enter in irrigation components manufacturing, should consider training as a vital element for survival and acquire it as an investment item.

204. **Financing.** Financing constraints can be considered as a major obstacle for the development of industrial sectors in general and irrigation manufacturing in particular in the developing countries. However, if the priority and the interrelation of irrigation equipment manufacturing and agricultural production and its role in food securing would be taken into account, the financial constraints could be overcome in most of the developing countries by choosing an appropriate policy and strategy for allocation of the available resources.

205. In addition to domestic financial resources almost all international financing institutes such as World Bank, Asian Development Bank etc., consider the financing of irrigation schemes as high priority projects for developing countries. In this connection, negotiation could be held with these agencies to extend their financial support to irrigation equipment manufacturing projects.

206. Other financing possibilities for establishing irrigation equipment manufacturing in developing countries are the following:

(a) <u>Utilization of export financing</u> of machinery suppliers' country

(b) <u>Financing through barter deals</u> (compensation)
This is a difficult task but there are a lot of such examples for financing industrial projects, therefore, this possibility could also be tapped for financing irrigation equipment manufacturing projects

(c) Supply of the machinery and buying of the product for re-sales in other markets can also be taken into consideration between the suppliers with international market share and those of developing countries which evident comparative advantage of manufacturing. This method is always to be realized with joint venture and is applicable to a limited number of products as well as countries

(d) BOT-deals
Build, operate and transfer (BOT) is usually applicable to low risk and high viability projects such as utility supply. For tapping this possibility, the market demand, tax and custom for importation of materials and other inputs, and orientation of sales prices towards international prices must be guaranteed for a limited period of time to make such deals attractive for the machinery suppliers or holding or financing companies usually interested in such deals.

207. Choice of one of the above or other methods of financing must be made for each particular case by assessing all possibilities to find the optimum solution.

VII. OBSTACLES AND BARRIERS IDENTIFIED TO ESTABLISH AND DEVELOP IRRIGATION PROJECTS AND/OR MANUFACTURING PLANTS FOR IRRIGATION EQUIPMENT

Problems associated with irrigated agriculture

208. It is apparent that the potential for increased productivity through irrigated agriculture in the developing countries is great but the performance of irrigation systems has been profoundly disappointing. Poorly managed irrigation has had serious adverse effects, including flooding, water-logging, increased soil salinity with destruction of the soil's productivity potential, and spread of water-borne and water-related diseases. Farmers at the tail ends of canal irrigation systems typically receive inadequate, untimely and unreliable supplies of water, discouraging them from adopting more productive farming practices. Crop yields remain low. Irrigation efficiencies, defined as the amount of water delivered to the root zones of the crops as percentage of the amount delivered, are generally as low as 30 per cent. While well managed irrigation systems show efficiencies of 60 per cent or more. There is great potential for increasing production as well as efficiency of water use.

209. Several deficiences in irrigation management arise from inadequate planning (with narrow objectives, lack of realism and neglect of non-irrigation aspects), defects in design (neglecting requirement for flexible operation, on-farm development and drainage) and especially from deficiencies in operation and maintenance. Many current deficiencies in irrigation management are linked with methodologies and institutional problems. Good irrigation management requires a multi-disciplinary approach and methods, but specialization leads away from this. In particular, civil engineering training and professional formation reward and value construction, but neglect and undervalue the vital activities of operation and maintenance.

210. Institutional changes are a national concern and responsibility but outside support can encourage and catalyse change. Actions are underway in most countries to remedy deficiencies but a multi-disciplinary flexibility is difficult within existing specialized institutions.

Obstacles of manufacturing plants for irrigation equipment

211. In most of the developing countries, a set of barriers hinders the development of capital goods sector in general and irrigation manufacturing in particular. Although the type of barriers may change from country to country, there are always some of them which are typical and have negative impacts on the development of manufacturing facilities. It is, therefore, necessary to try and make some of them apparent.

(a) Market size which is usually discussed together with the economies of scale of manufacturing, can be regarded as a major barrier to the development of the irrigation equipment manufacturing in developing countries. Regional or common market between some developing countries can be considered as a counter measure in this regard.

(b) Fluctuation of domestic market demand which is specially observable on the agricultural machinery market in general and irrigation equipment in particular, is probably as important as the average market size itself. No industry can exist in an environment of dramatic peaks and troughs. To reduce the probability of fluctuations occuring, careful planning and consideration of multi-purpose or flexible concept of manufacturing may be helpful, however, is not always easy to realize and implement.

(c) Lack of capital is another major constraint.

(d) Compared to all other industrial sectors, the need for skilled manpower is the highest in the case of the capital goods industry in general and irrigation manufacturing in particular. Training of skilled and semi-skilled manpower takes time. Short-term solutions are not always possible even if the financial resources are available.

(e) Lack of socio- and technical infrastructure can be of major disadvantages for realization of irrigation equipment manufacturing plants. Lack of basic technical services such as casting, forging, heat treatment etc. constitute some of the technical infrastructure required for manufacturing of irrigation and other agricultural machinery.

(f) Lack of supply of raw materials (iron and steel) and other metals (aluminium) and feeding industry (electric motors, gears production etc.) can increase supply shortages, due to lack of foreign currency for import or difficulties in obtaining import licenses.

212. For more detailed explanation of industrialization constraints in developing countries, a number of published documents are available within UNIDO and other United Nations agencies.14/

VIII. STRATEGIES AND POLICIES (ROLE OF INTERNATIONAL CO-OPERATION)

213. Irrigation has continuously gained importance in the civilization of mankind. Most men who are well informed on irrigation are certain of its perpetuity, as long as it is intelligently practised. The duration of civilized people is probably dependent on many factors, of which a permanently profitable agriculture is vitally important.

214. The importance of irrigation in the world today is well stated by N.D. Gulhati of India:

> **"Irrigation in many countries is an old art, as old as civilization, but for the whole world it is a modern science, the science of survival."**

215. The pressure of survival and the need for additional food supplies are necessitating a rapid expansion of irrigation throughout the world. Even though irrigation is of first importance in the arid regions of the earth, it is becoming increasingly important in humid regions.

216. Experience gained during the last decades in the USA and by major producers of agricultural products has shown that the irrigation of cultivated land is an effective measure for safeguarding the supply of the world's food requirements.

217. Approximately 250 million hectares of cultivated land are being irrigated worldwide, especially in arid regions, which make up about 15 per cent of the total cultivated land. On this comparatively small portion of cultivated land, approximatively 30 to 40 per cent of the total food is being produced.

218. Efficient and appropriate irrigation calls for a variety of machinery and equipment. The non-availability in the market or very high prices of irrigation equipment are the major constraints in most of developing countries for proper application of irrigation systems by most of the farmers.

Therefore, in line with other measures such as:

- Access to land and natural resources
- Access to input and services
- Access to distribution channels, marketing, processing prices and incentives
- Access to institutions
- Access to education and training
- etc.

the necessary facilities for economic production of key agricultural machinery in general and irrigation equipment in particular must be provided.

219. As key components of modern irrigation, production of quick-coupling pipes, made of galvanized steel or aluminium, is recommendable.

220. Quick-coupling pipes and sprinkers are the key components of pipe sprinklers irrigation systems. Pipe sprinkler systems can be applied to a large variety of lands; labour intensive systems (portable and handmove) as well as fully mechanized systems such as solid set are accomplishable by having quick-coupling pipes and sprinklers at disposal. Pipe sprinkler systems are suitable for small-scale irrigation schemes, therefore, they are of high value for a large number of developing countries.

221. Manufacture of quick-coupling pipes is accomplished by a pipe mill; for steel pipe by E.R.W. and for aluminium by non-ferrous welding processes. The pipes diameters (50 to 220 mm) and the required wall thickness and its resistance to pressured water call for specially designed pipe mills.

222. For the manufacture of coupling and other necessary fittings, standard workshop operations such as cutting, pressing, machining, welding, assembly etc. are required which might be accomplishable in multi-purpose capital goods manufacturing facilities. For manufacture of sprinklers, casting facilities (die castings) for non-ferrous metals are required.

223. The skills and know-how for the above mentioned workshop activities are readily available in most of the developing countries. The required design details and production know-how for these systems must be acquired.

224. Production of drip irrigation systems' components can be recommended for a large number of developing countries. The production process is rather simple and mastering of the same can be achieved in a short period of time.

Policy and strategy at the governmental level

225. For the realization of irrigation equipment manufacturing facilities in developing countries the following policy and strategy can be taken into account at the governmental level:

(a) Support the systematic investigation of agricultural lands and possibilities of application of the various irrigation systems.

(b) Based on above founded and detailed investigation, the potential market and effective market for irrigation components and equipment should be estimated and forecast for the same in the short and long terms must be made. Such market survey could be supported by the government.

(c) Support the preparation of detailed feasibility studies for the manufacturing of irrigation components determined in the course of the above market investigation. By implementing such feasibility studies the various production technologies and application of multi-purpose facilities could be investigated, compared and optimal solution selected.

226. Of major importance will be the working out of governmental strategy and policies for promoting the irrigation equipment manufacturing projects. These promotion policies should provide the necessary incentives for the private sector to invest in irrigation equipment manufacturing. Promotion measures could be such as:

- Tax and duties exemption for importation of manufacturing machinery and facilities
- Tax and duties exemption for importation of raw materials and inputs
- Income tax holidays (for at least 5 years)
- Governmental protection measures such as application of customs and duties for importation of the irrigation components already manufactured locally, etc.
- Providing soft loans for implementation of irrigation equipment manufacturing projects
- etc.

227. Support research and development for irrigation in general and irrigation equipment and systems suitable for local conditions in particular. Involvement and co-operation with local consulting and engineering companies and groups from initiating phase to post implementation phases for the realization of any project.

228. Choice of an appropriate project realization method, e.g. doing all basic engineering and detailed engineering by a project management and project engineering task force. All individual pieces of equipment or contract disciplines be placed for competitive bidding. In other words, avoiding the turn-key project implementation method. Of course this method of project implementation in comparison to the turn-key method is more difficult and requires more skills to implement but, on the other hand, is the only possible method for local engineers to learn on-the-job, how to design, implement and monitor the project implementation. This system also ensures the retention of control by the client of the facility features and also ensures that the most competitive offer for each component of the project is acquired without any mark-up by any contractor. It avoids the major disadvantage of turn-key contracts; loss of control over desirable design and installation features without suffering price changes which are not subject to competitive bidding disciplines.

Policy and strategy at the international level

229. The "one world" concept is not new. Spaceship Earth is an accepted metaphor in the United Nations. In 1980 the community of nations adopted an international development strategy reflecting their recognition of essential and comprehensive interdependence among nations. In this context tapping the international co-operation possibilities for successful realization of irrigation components manufacturing will be one of many good examples of international co-operation. The most important areas of international co-operation are:

(a) **Capital and technical assistance.** Capital and technical assistance to developing countries, both multilateral and bilateral, has become an important part of the international framework of agriculture and will play a key role in the modernization of agriculture in developing countries. In this connection utilization of some of foreign aids for implementation of agricultural equipment manufacturing in general and irrigation equipment manufacturing in particular is possible and is of benefit for developing countries.

(b) **Research and transfer of technology.** Attainment of the necessary long-run growth of agricultural productivity which is dependent on irrigation and application of irrigation equipment must be based, among other things, on technical innovations. Much irrigation research and derivation of technologies is area-specific and must be carried out within the country concerned, often with reference to conditions particular to individual regions, but it must be integrated and cross-fertilized internationally.

(c) Joint ventures for producing irrigation equipment will be a good means of promoting such projects.

(d) Conduct of regional co-operation, between a number of developing countries. This will be a good counter-measure for lack of adequate demand for starting an economic production of irrigation equipment in some areas.

(e) Compensation arrangement (barter deals) for financing irrigation equipment projects.

Notes

1/ Milos Holy, Bewaesserungswirtschaft, 14. Jahrgang, 1. Heft, April 1979.

2/ Food and Agriculture Organization of the United Nations (FAO), "Water quality for agriculture" (FAO Irrigation and Drainage Paper No. 29), Rome 1976.

3 G. Garbrecht, Bewaesserungswirtschaft, 14. Jahrgang, I. Heft, April 1979.

4/ Bewaesserungswirtschaft, page 110, 14. Jahrgang, I. Heft, April 1979.

5/ Eaton and Harding, 1959.

6/ Hagan, Haise and Edminster, "Irrigation of agricultural land", Agronomy No. II, 1967, Madison, Wiscounsin, USA.

7/ FAO, "Crop water requirements" (FAO Paper No. 24).

8/ Beckett and Robinson, "Irrigation of agricultural land", Agronomy No. II, 1967, Madison, Wiscounsin, USA.

9/ "Irrigation of agricultural land", Agronomy No. II, 1967, Madison, Wiscounsin, USA.

10/ Carter and Hartwig, 1962; in Ibid.

11/ Whit and Van Bavel, 1955; Herpich, 1963; in Ibid.

12/ Marr and Hemphill, 1928; Eric, 1963; in Ibid.

13/ Harris and Hawkins, 1942; Beckett and Dunstee, 1932; in Ibid.

14/ - United Nations Centre for Science and Technology for Development, "Statistical survey of endogenous capacities in science and technology for development", May 1983.

- United Nations Industrial Development Organization (UNIDO), "Electric power production in developing countries. An analysis of eleven country case studies", Sectoral Studies No. 25 (UNIDO/IS.507 and UNIDO/IS.507/Add.1) and No. 26 (UNIDO/IS.509), 1985.

- "Methodology for analysis of obstacles and their remedies in technology transfer in the Arab region" (E/ECWA/NR/SEM.3/BO.5), 1981.