# Strategies And Technologies For Implementing Rural Biogas Programs In Latin America

Serial: Olade's documents
Second Edition No. 11

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# STRATEGIES AND TECHNOLOGIES FOR IMPLEMENTING RURAL BIOGAS PROGRAMS IN LATIN AMERICA

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# STRATEGIES FOR IMPLEMENTING RURAL BIOGAS PROGRAMS IN LATIN AMERICA

Among its programs, the Latin American Energy Organization, OLADE, contemplates the development, promotion and diffusion of Biogas technology destined to the rural areas of Latin America.

OLADE has surveyed the Latin American region with the object of discerning different opinions with regard to this technology and of learning the relative level of progress in research programs or development. The results have demostrated wide diversity of opinions with relation to this theme. There are some governments, private groups and organizations that have made promissing advances. There are opinions to the contrary that are based, in general, on concepts which do not reflect a real awareness of the possibility of solutions for many problems, solution facilitiated by the implementation of biogas programs, especially in regions that are marginal to the supply of services rendered by society, as is the particular case of rural Latin American communities.

A justification of the problem will be put forth the following four basic aspects:

1. Ecological Aspects
2. Socioeconomic Aspects
3. Technical Aspects
4. Governmental or National Aspects

## 1. ECOLOGICAL ASPECTS

A series of great problems exists in Latin America, and the world over:

Energy crisis
Food crisis
Pollution crisis
Depredation crisis

Without going into a discussion of causes and responsibilities, the truth or falsity on a world scale, it is necessary to analyze the following proposal in order to find a solution:

ANAEROBIC DEGRADATION TECHNOLOGY FOR BIOMASS CAN COLLABORATE IN PERMANENTLY AND SIMULTANEOUSLY RESOLVING THESE PROBLEMS WITHOUT SOPHIMS, ON VERY DIFFERENTE SCALES, ON AN URBAN AND/OR RURAL LEVEL, CONSIDER:

### a. Energy

The efficiency of this process of bacterial biodegradation can reach about 80 o/o. With regard to energy, that means a high recovery index among its biological forms that, at present, cause problems: excrements, manure, garbage, aquatic quartz, impoverishment of soils and forests. As can be observed, when this happens it coincides immediately with depollution. Simultaneously, it tranforms such wastes into nutrients so as to assist in improving soils and harvests.

Without discussing the concentration (density) of the source, several points must be indicated:

— It is a decentralized source of energy and nutrients.

— It permits the intensive use of local labor in this construction. It optimizes rural labor in its operation.

— It doesn't produce expenditures of human energy in disposing of wastes, nor expenditures of the same when handling low concentrates of agricultural wastes, in order to improve soils; it recovers, concentrates, finalizes, localizes and applies these organic fertilizers in the required sites (where more nutrients are extracted through permanent harvests).

-- It avoids dead times among the majority of peasants' rural activities (monoculture, shepherding, pasturing, etc.).

— It is the only system of energy production that aids in protecting several of the other energy sources.

By protecting and recovering the plant cover via nutritional improvement of the soil, deforestation and erosion are reduced, and rapid loss of the hydroelectric resource is avoided not only by depending on electrostatic attraction that fixes clouds but also by substituting water for dirt (sludge).

By substituting the loss of trees with:

a) Energy (firewood and coal)
b) Unoccupied times (shepherding, generally excessive)
c) Extensive, advancing agriculture.

Thus, the forests and their fertility may remain in order to make "energy crops" through the various non—conventional forms (gasification, leaven, etc.).

Other crops would be those which produce alcohol, for instance:

Sugar cane
Seaweeds (algae)
Yccat
Aquatic quartz

Otherwise, they will only be aerobically consumed in degradation, without being able to contribute to anything more than to pollution. Likewise, the poor people's energy will continue being lost and they will encroach upon that of the rich: methanol, hydroelectricity, ethanol, etc., and consequently petroleum and its derivatives.

**b) Improvement of the Agronomic Conditions**

As has been said, the recycling of nutrients (another form in which energy exists) permits substantial soil improvement:

### Conservation and Improvement of Soils

Organic material for:

- Good pH
- Moisture retention
- Settling of degrading micro flora and fauna
- Anions and cations for disposing of certain nutrients otherwise non—assimilable
- Protection from inclement weather
- Long—term nutrients

Nutrients, fertilizers:

- Volatile Nitrogen is not lost as much due to the fact that it is enclosed as to its low temperature and its ability to mix in organic compunds.

- The hormones, micronutrients, etc. are not lixiviaded in non—recoverable liquids.

- Vitamins, hormones, etc. are not burned up in thermophilic reactions, such as the aerobic.

- Other compunds are not oxidized and thus destroyed.

Larvae eggs, which carry plagues (chicken blindness, moths, nematodes, etc.) die; with aerobic fermentation, the destruction of the eggs of nematodes and other is not achieved.

- On being nourished in a balanced way (because what is extracted from the soil is not lost), plants become more resistent and productive.

- Certain spores, bacterias, etc., are sterilized.

Likewise, it permits intensive use instead of extensive use of the soil (and water) and polycultivation, which maintains more permanent levels of production and employment thus increasing productivity (not only the mirage of "production") and diversification.

The soil and the plants are improved and provide more and better nutrients, at the same time optimizing human and animal diets.

Finally, they relieve expenditures, both internal and external: they create broad sources of work by producing, with adequate technology, fertilizers with the additional value of producing energy, instead of expending it as in traditional technology.

### c) Pollution

It substitutes problems in resources by taking advantage of most of the present and potential pollution, by establishing a basic link between death and the generation of new life: life that is no longer proper to the waste; the breakdown (death) in the digester and the availability that it provides for the new plant and animal life feeds on the previous one.

It avoids the sophisms that exist in the supposed "treatment" system of sewage and aerobic type garbage, in which energy is spent in "burning up" that which it has.

From the point of view of sanitation, the bacterial content, the viability of eggs, larvae, etc., are considerably reduced, as are the seeds of weeds (which, in a way, pollute crops through excessive proliferation and later through soil abuse due to the breaking of new land and the use of herbicides).

It avoids the spraying of lixiviated chemical fertilizers on the surface with its consequent disequilibrium of diets and growth, increase in DBO, etc.

On increasing plant resistance, it avoids the abuse of insecticides, fungicides, etc.

By permitting the intensive use of the soil through perpetual polyculture, plant and animal diversity is increased; and the ecosystem's natural defenses are thereby improved. Thus, since pesticides are not required, there are places for all the species and biological self—control is established (each creature and its predator in a chain).

**d) Depredation**

Examples for this particular subtopic have abounded in the preceding ones. It only remains to reiterate the general idea of the topic and to point out some other examples that emphasize the feasibility of resource recovery as opposed to depredation.

The digesters are an essential in the scheme for the recovery of vital resources such as water and nutrients. It must be pointed out that in the case of waste water resulting from human use (abuse), a double absurdity exists: we throw out several resources with the water and, on doing that, we pollute (attack, kill) rivers, lakes, and seas.

Not only in rural communities, at a household level (for instance, the Mexican SUTRANE), but also on a grand scale in urban sewage systems (Bremen, Germany; Philippine aquaculture, the U.S.A., the Mexican Dual Plant, among others), the digesters have proved to be irreplaceable for treating water and producing energy (including nutrients).

They are virtually insurance against droughts, given that certain kinds of them permit an optimum and scaled use of a water supply.

As a result, referring to all that previously set forth, from the ecological viewpoint, the most adequeate strategy for implementing biogas programs is the following:

a) Being the program on a small scale, with residents from rural areas who require firewood consumption for cooking their food and who work in agriculture (with the necessity of using fertilizers, although that may not have been their custom).

b) Principally in regions whose forests are being depredated for these ends and where the residents are beginning to feel a crisis in obtaining this resource.

c) In agricultural regions whose evironmental pollution (rivers, soil, and air) is occasioning living problems.

d) In agro—productive regions with degraded soils and problems in their capacity for retaining nutrients and/or water.

e) In areas with abundant, but unused or underused, waste production (people or communities with the custom of making composts, in order to improve the nutritional condition of organic fertilizers).

## 2. SOCIAL AND ECONOMIC ASPECTS

The social and economic justification for this program is very diverse; but everyone is aware of the basic characteristic of the rural areas of developing countries, principally. Most people in rural areas are dedicated to agricultural activities, and many of them inhabit isolated, scattered areas without productive resources (among which energy and fertilizer are of great importance); moreover, their cultural conditions keep them removed from the sophisticated technologies that permit improvements in their standard of living.

Traditional customs among rural inhabitants are very diverse, but in many of these cases it is difficult to convince them to effect radical changes in their traditions, at least if the convinving is not done by using simple, practical, and efficient means of demostrating the results.

The economic aspect of the residents of this region implies limitations, based on the fact that any attitudinal change with regard to their traditions is more easily achieved when the benefits are obtained with low investment costs (with active labor participation) and to improve their living conditions.

Consequently, useful strategies permitting the implantation of national biogas programs in rural areas must consider the following aspects:

a) In spite of the fact that most people would be considered potential users, attending the necessities of initiating a program of this nature, it becomes necessary to detect an appropiate type of user who guarantees a successful diffusion. Sometimes this kind of person isn't the neediest, but rather he who is more worried helping and serving his community.

b) It is important to detect teaching centers, families, groups and communities that are susceptible to accepting and implementing biogas programs and that have the necessary facilities, organization and support.

c) Guarantee simple, direct campaigns to educate and train rural residents, with the idea that, based on their own incentive and interest, they will become involved in medium —and long— term participation.

d) Support peasant groups so that they will organize productive activities for the use of digesters in an integral way.

e) Train national work teams dedicated to promoting rural development, that can coordinate or organize the interest groups or those who demand service.

f) Establish real show places in strategic locations which respond to the solution of common or manifest needs.

g) Demonstrate the socioeconomic impact of the digesters.

h) Involve the government or collateral and private organisms in order to guarantee the program's multiplier effect. This effect is achieved by directing the communities toward marking their own efforts and constructions, by pointing out necessities and diffusing that technology appropiate for their conditions.

i) Establish agreements with users to implement and give continuity to the program. It is the only means of committing the user's participation.

j) Establish the macro—economic work area with the support of:

—The government, in the construction of show places
—Private enterprise, in a cooperative function; and,
—Institutions of Community Services, in order to reinforce training and diffusion programs.

## 3. TECHNICAL ASPECTS

Biogas technology is, without doubt, almost totally unknown among most Latin American rural inhabitants. However, with the experience obtained so far in small—scale, isolated programs, at the moment of seeing the results, the residents become interested. Such technology is basically adaptable to any cultural and technical level. It does not require complex aspects nor does it imply dependence on outside economic or technical resources.

Nevertheless, in the initial phase (pilot plants), the construction of the plants requires basic knowledge and materials, possibly difficult to obtain in certain rural areas, especially marginal ones (iron rods, bricks, cement, PVC pipes, etc.). Furthermore, with the object of transmitting basic construction details, it is useful to realize the design with conventional materials; but in any case there is the alternative of realizing any subsequent construction with local materials and appropriate technologies. The important thing is to be aware of basic structures.

The technology for the operation or management of the plants is equally simple; however, different degrees of difficulty arise with regard to fermenting different raw materials (mainly, plant wastes whose organic compositions have high resin or complex material content).

Considering the aforementioned aspects, the basic strategies for implementing the initial phases or program of this nature must take into account the following aspects:

a) Develop simple, direct programs which train rural work groups to disseminate the technology (construction, operation and utilization).

b) Create construction teams that lend support when needed.

c) Extend services on all levels, without charge, to the rural areas.

d) Due to the fact that different kinds of technology exist, with different applications, it becomes useful to diffuse more than one kind of thechnology in each country, for the purpose of reducing the inappropriate application of technology, which might incite a loss of confidence in this program, were satisfactory results not obtained.

e) Take into consideration the user's needs, with relation to biogas as well as to biofertilizer.

f) It is useful to be aware of the local construction materials, soil type, freatic level, and available labor.

g) Elaborate audiovisual material and practical manuals on the subject.

h) Keep a conventional record of operational problems that arise on the level of the user, in order to correct future defects.

i) In the initial phase, utilize aspects that simplify the anaerobic digestive process (preferably warm climates, cereal plant wastes, animal wastes, mainly cattle manures, horse manure, and suvine manure) and recur to the use of mixtures, preferably all those that guarantee rapid fermentation.

j) It is indispensable that liquid, sludge, and/or solid biofertilizer be used in agriculture to avoid its accumulation and disuse, again constituting waste, without completing its cycle.

k) Guarantee governmental programs that give continuity to the pilot plants because, otherwise, without having rooted the technology within the daily life of the user, there exists a tendency to abandon the use of the plants, with the consequent devalorization of a program whose benefits do not become observable until its implementation.

In the pilot plants, demostration activities will be carried out with respect to the efficient use of gas in stove and oven burners, lamps for illumination, refrigeration, drying of agricultural products, stationary motors, etc.

1) The execution of research and development programs on the part of institutions dedicated to this kind of work (institutes for technological research, universities, etc.) is necessary for the purpose of learning about the most important variables of the anaerobic fermentation process and linking these results to the biogas pilot plants. This work should have medium—term application, avoiding possible duplication of effort.

At the national level, the benefit that the use of this technology represents will only make itself felt when its implementation is massive. As a result, the follow—up phase is of great importance.

## 4. GOVERNMENTAL OF NATIONAL ASPECTS

The attitudinal diversity among different Latin American governments makes it difficult to sustain common strategies. However, this document makes general proposals with the idea that, according to the nature of development interests in the various countries, concrete positions can be contemplated for the support of a program that protects ecology and plant, animal and human health, in addition to freeing the rural area from energy dependency and guaranteeing the production of organic fertilizers in optimum conditions, which directly coincide with the production of more and better foods.

The fact that programs destined to the rural sector must be channeled through government programs is definitive. Depending on the state structure, the role played by private enterprise and service organizations or community groups not linked to the central government becomes very important, Generally, private initiative can do very little in the development of programs of this nature in rural areas, mainly because labor, as well as construction materials, are preferably products of the location in question. Nevertheless, within the business sector there will always exist, in some cases, a demand for material and equipment that could, through special governmental concessions, guarantee an efficient supply with a reduced profit, with the aim of aiding programs destined to this sector (iron, PVC pipes, water pumps, internal combustion engines, electric generators, etc.).

The principal strategies to be considered at a national level are the following:

a) Consider the participation that OLADE can offer in the corresponding energy sector, in its function as a regional organism responsible for the development of this type of programs.

b) The government, as a directing body, must establish mechanisms to integrate the activity of its different institutions (energy, agriculture, rural development, education, health, and credit) in order to permit the integral participation of its efforts at action in a program such as this, which includes different fields of action.

c) As governments begin to understand the possibilities of this technology, after having established pilot plants, it is useful for them to implant national biogas programs, in order to guarantee success and, furthermore, to coordinate the channeling of actions that a group international organisms or institutions is attempting to develop in Latin America.

d) A relationship between the government and those private institutions that may serve as support for the program is recommended.

e) When the respective Ministry of Energy does not exist, the formation of National Councils for non—conventional energy sources is also useful, in order to facilitate the action of those international organisms which, like OLADE, require a link to the dicision—making power within the governments.

f) It is recommended that the governments select one of their institutions, to coordinate activities regarding the production and use of biogas at the national level; in addition, this coordinating office will be in charge of gathering and diffusing information on this subject.

g) After these phases, the governments can have a broad vision of the real situation within their own countries, and thus they can define national and international credit policies that guarantee massive development of this kind of technology.

It is almost certain that to the degree that energy problems becomes intensified, sooner or later, this kind of offer will have to be integrated into national development programs based on the innumerable quilities described previously.

In that regard, it is imperative for governments to begin to evaluate the different sectors in which this technology can be used, through the establishment of pilot plants, so that when awareness with regard to renewable and non—conventional energy becomes a necessity, they will be able to define their parameters of action, knowing all the limitations regarding the same.

## II. DIFFERENT TYPES OF BIOGAS TECHNOLOGY FOR RURAL AREAS IN LATIN AMERICA

The stage of technological development currently reached with respect to Biogas offers proven solutions for the rural areas of Latin America. The massive experiments carried out by the Chinese, Indians, and others in relation to the adaptation of this highly developed technology for application under the cultural and socio—economic conditions of those regions' rural inbatitants, guarantee its massive success. In addition, Latin America has developed its own technologies suited to its particular conditions.

Having carried out in—depth analyses of the different types of biogas plants in existence, it has been thought basic to put forth those having the greatest backing with respect to simplicity of operation. Each technology has a different application. In ideal conditions, they are all highly efficient. The problems arise when a technology is badly utilized, inadequately managed and poorly established. There is no universal technique. Neither is there a common need.

The users of this type of energy (families, communities, small agricultural holdings) differ greatly with respect to the aspects they desire to obtain from this technology. Besides, if we consider its fundamental impact on the different sectors (energy, agriculture, nutrition, health, ecology, etc.) it is also impossible to criticize or compare the different technologies. Neither can they be compared in economic terms, since their impact goes in different directions and is often difficult to evaluate.

OLADE has thought it useful to begin a program reinforced by the participation of experts in the different technologies, articulating the general characteristics of each one. This can serve as a starting point for becoming acquainted with knowledge outside the reach of many nations and people already related to, or potentially interested, in the program.

# 1. BIOGAS PLANT: OLADE–GUATEMALA TYPE

## 1.1 BASIC DESIGN

### Generalities

This plant consists of a set of digesters and a separate gasometer. The reason for having more than one digester is that when one is being loaded or unloaded the other(s) will always be working. A gasometer is understood as an inverted bell, which is submerged in a tank of water and which stores, measures and pressurizes the gas in order to distribute it to the consumption lines.

### Form

Digester: the digesters are cylindrical in shape, with a vertical axis and with the height preferably equal to the diameter. Located above–ground, it is on a base, preferably below ground, designed to isolate the digestion chamber from the temperature changes in the ground; this is mainly affected by moisture. The digester is loaded through the upper part, which has an opening for inspection purposes, with a hydraulic seal. The emptying of the liquid is done through a drainage pipe placed on the lower lateral part of the digester. The emptying of solids is done through the inspection cover, as well as through a lateral door (built for this purpose) at the bottom of the digester.

### Gasometer:

The gasometer is a cylindrical storage tank, above or below ground, with a diameter similar to its height, and whose size corresponds to the size of the gas–collecting bell, inverted over it. The storage capacity should be designed in accordance with the consumption needs; but in general, it is suggested that its volume be equivalent to half of the average daily gas production.

Gas–conducting Pipes: The gas circulates from the digester to the gasometer, or from the latter to the consumption lines, through pipes preferably of an anti–corrosive material provided with cut off valves strategically placed at the outlet of the digesters, as well as at the entrance and outlet of the gasometer. Just before entering the gasometer, the pipe should have a water–trap, for the condensate and principally, with a slope convenient for capturing the same.

### Loading

The tipe of loading and unloading of this digester is by batch (discontinuous charge), with dry and solid organic material. That is to say, this activity is competed in one, single operation with discharging taking place until the digestion cycle ends.

### Location

Because the digester is designed for agricultural use on a large or small scale, its location should be near a stable or source of raw material. Nevertheless, the gasometer could be located near the place of consumption, to permit easy observation of the quantity of gas available.

## 1.2 CONSTRUCTION MATERIALS

These can vary greatly depending on the availability of local construction material. "Hormigon" (reinforced concrete), bricks and even ferrocement can be used. Also, if construction is to take place in a rural zone very far from a place where iron materials are available, substitutions can be made with bamboo or other hard fibrous plant materials.

An example of a small–scale plant is presented below, with two digesters, of 9 $m^3$ each, and a gasometer with a storage capacity of 4.8 $m^3$; it could be used on a small farm with 10 head of cattle, stabled at night, and proportional volumes of agricultural waste.

The materials are calculated for a seismic zone and ferrocement construction.

It should be mentioned that the safety limits contemplated herein can be reduced considerably for the purpose of lowering the costs of construction, principally in areas with little seismic risk. The thickness of the walls may be reduced by using PVC pipes instead of galvanized pipes; the covers and the gasometers may be constructed from galvanized plated reinforced with iron, fiberglass, ferrocement or plastic rings, etc. (taking into account that one of the gasometer's objectives is to generate consumption pressure, i.e., to supply additional weight in order to achieve the equivalent pressure).

### MATERIALS LIST FOR CONSTRUCTION OF AN 8.50 $m^3$ DIGESTER IN FERROCEMENT

| MATERIAL | QUANTITY | |
|---|---|---|
| Cement | 50 | bags |
| River sand | 3.50 | $m^3$ |
| 1/2" and 3/4" gravel | 2.00 | " |
| Boulders | 1.00 | " |
| Choice material (refractory) | 0.50 | " |
| Ash (or live lime) | 0.50 | " |
| 1/4" x 12 m. iron | 55 | iron bars |
| Lashing wire | 15 | kg. |
| Blocks 0.15 x 0.20 x 0.40 | 170.00 | units |
| 1/2" wire mesh | 50.00 | yd 2 |
| Polyethylene plastic | 15.00 | $m^2$ |
| Waterproofind agent | 15.00 | kg. |

### PUMBING BETWEEN DIGESTER AND GASOMETER

| | | |
|---|---|---|
| 2 — Permatex pipes | 2 | units |
| 6 — 1" couplers | 3 | " |
| 12 — 1" elbows | 10 | " |
| 6 — 1" universal joints | 2 | " |
| 4 — 1" T–joints | 3 | " |
| 12 — 1" x 4" nipples | 9 | " |
| 2 — 1" male plugs | 2 | " |

| | |
|---|---|
| 1 — 1/2" — 1" reducer cover | 1 " |
| 4 — 1" stopcocks | 5 " |
| 4 — 1" galvanized pipes | 4 " |
| 1 — 1/2" galvanized pipe | 1 " |
| 1 — 2" galvanized pipe | 1 " |
| 2 — 4" x 12" nipples2 | 2 " |
| 2 — 4" stopcocks | 2 " |
| 2 — 4" screw — on nipples | 2 " |

$y^2$ 91 x 91 cm.

**DIGESTER COVER**

| MATERIAL | QUANTITY |
|---|---|
| 1. Black sheets 4' x 8' x 1/16" | 3 units |
| 2. Iron rods (or female plates) 1 1/2 x 3/16" x 20' | 2 " |
| 3. Anchor reinforcements Welding | 4 " |

**GASOMETER**

| | |
|---|---|
| 1. Sheets 4' x 8' x 1/6" | 5 units |
| 2. Flat iron strips (or female plates) 1 1/2 x 3/16 x 20' | 4 " |
| Welding | |

**GASOMETER SINK**

| | | |
|---|---|---|
| 1. Cement | 10 | bags |
| 2. River Sand | 1 | $m^3$ |
| 3. 1/2" and 3/4" gravel | 0.75 | $m^3$ |
| 4. 1/4" x 12 m. iron | 8.00 | iron bars |
| 5. Galvanized wire | 3 | kg. |
| 6. Blocks 0.15 x 0.20 x 0.40 cm. | 150 | units |

## 1.3 CONSTRUCTION TECHNIQUES

These vary depending on the type of the construction selected. Below are some basic aspects:

a) Base of the digester: its objective is to impede the direct contact of the digester with the moisture in the ground, in order to act as thermal insulator.

b) Water—proofing: it is necessary to make the inside of the digester impermeable in order to stop the seepage of moisture and / or gas through the walls; the same goes for the interior of the gasometer's water tank, to prevent water filtrations.

This impermeability can be achieved with different types of materials, depending on their local availability, but it is essential that they fulfill their porpose.

c) Other details: the pipe for conducting the gases. It is very important that the parts joined to the valves, nipples, etc., be perfectly and hermetically sealed to prevent any leakage that could interfere with the proper functioning of the digester through loss of pressure.

d) Gasometer: The pressure required to raise the gasholder should not exceed a 15 cm. column of water. The water seals for the digester covers as well as for the water—trap for the condensate equal 30 cm. which provides an ample margin of safety. Nevertheless, it is very important to avoid any friction in the free movement of the bell, which would impede its displacement, with possibility of increasing the internal pressure of the digesters; (in extreme cases) this could cause cracks in the construction. In case the cover of the gasholder is not heavy enough to provide sufficient consumption pressure, this can be aided with heavy materials such as stone, bricks, etc., until the required pressure is attained.

Ilustrations of the construction of the digester and gasholder, with the ferrocement technique follow:

## 1.4 RAW MATERIAL FOR THE DIGESTER PROCESS

The materials used in this technology of low dilution (40 to 60 o/o solids in solution, depending on the density of the material) vary greatly. With this system it is possible to digest methanogenically with some variation—materials not easily digested with techniques of high dilution and continuous or semi—continuous load. Preferably, animal waste is mixed with waste to obtain an appropriate ratio of carbon/nitrogen, in order to achieve a bio—fertilizer of superior organic characteristics.

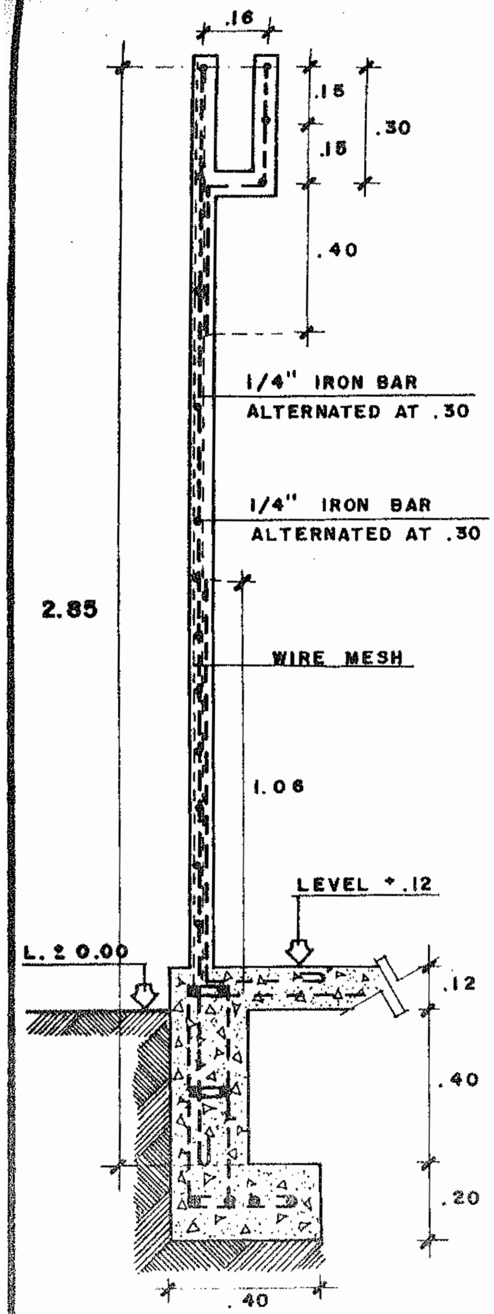
A digester has been operated efficiently with the use of residue from grain crops (corn, rice and wheat); sugar cane bagasse; pulp or husks from coffee, aquatic plants; waste from bananas, tabacco, and beans; animal manure in general; and composted organic waste.

The animal manure should not be less than 1/3 of the volume, which can be augmented with plants having a low content of organic matter and high levels of cellulose. It is also useful to consider the addition of mineral nitrogen, urea, to aid in providing the nitrogen required by the bacteria in order to function in this environment.

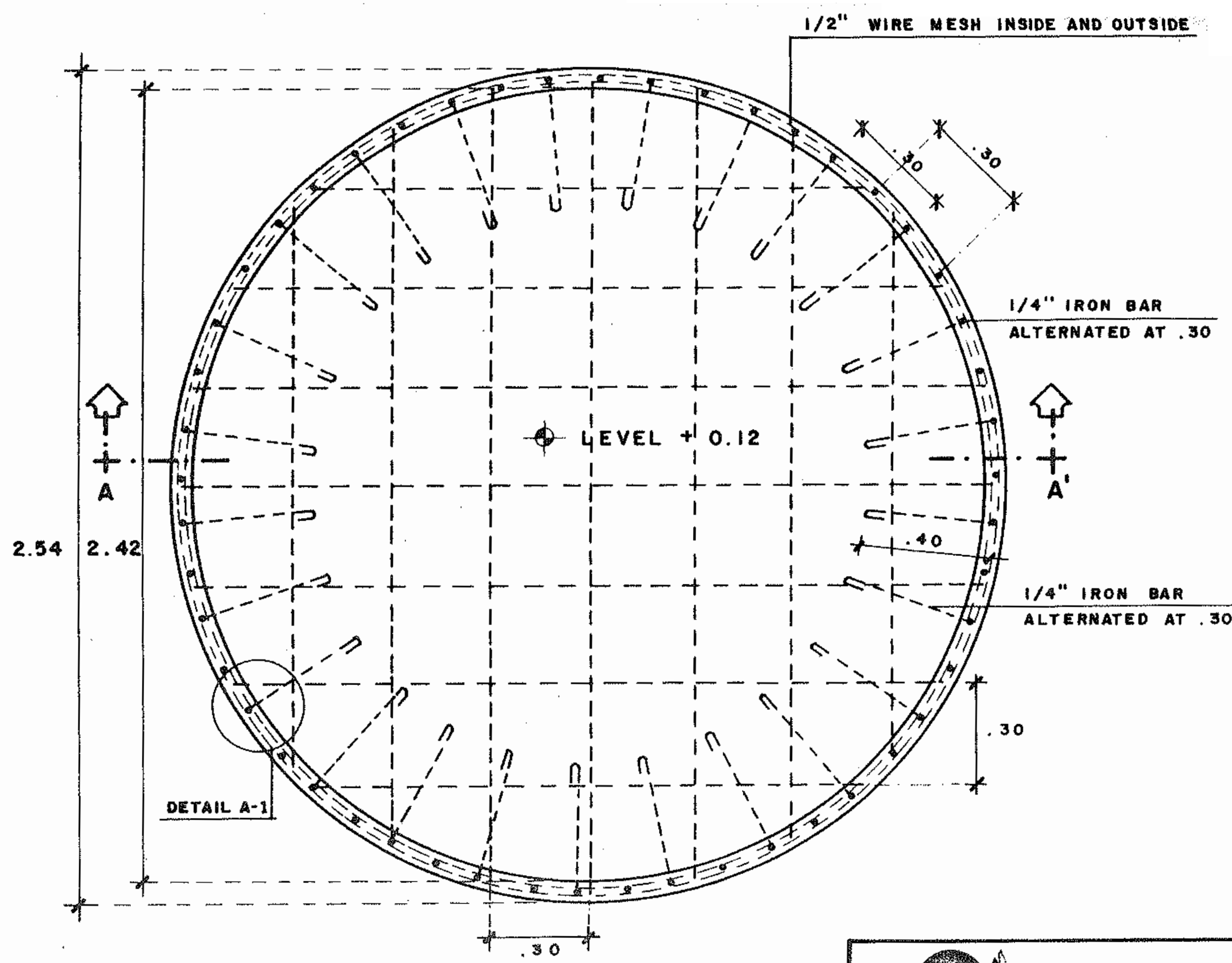
## 1.5 OPERATION OF THE DIGESTER

The loading of the digester begins this phase. The material to be used should have been previously composted in the open air for ten or fifteen days, a process which besides allowing for an easy beginning to the digestion process, reduces the humidity contained in the fresh material. This action is necessary (although not essential) to facilitate the compaction of the material inside the digester before it is completely filled.

When the digester is to be loaded with only one kind of material, the operation should be done in layer 30 cm. thick, successively compacted. When the load is comprised by a mixture of materials to be deposited.




DETAIL A-1 SCALE. 1:20




IRON REINFORCEMENT

(PLANT BASE) SCALE. 1:20

DIGESTER

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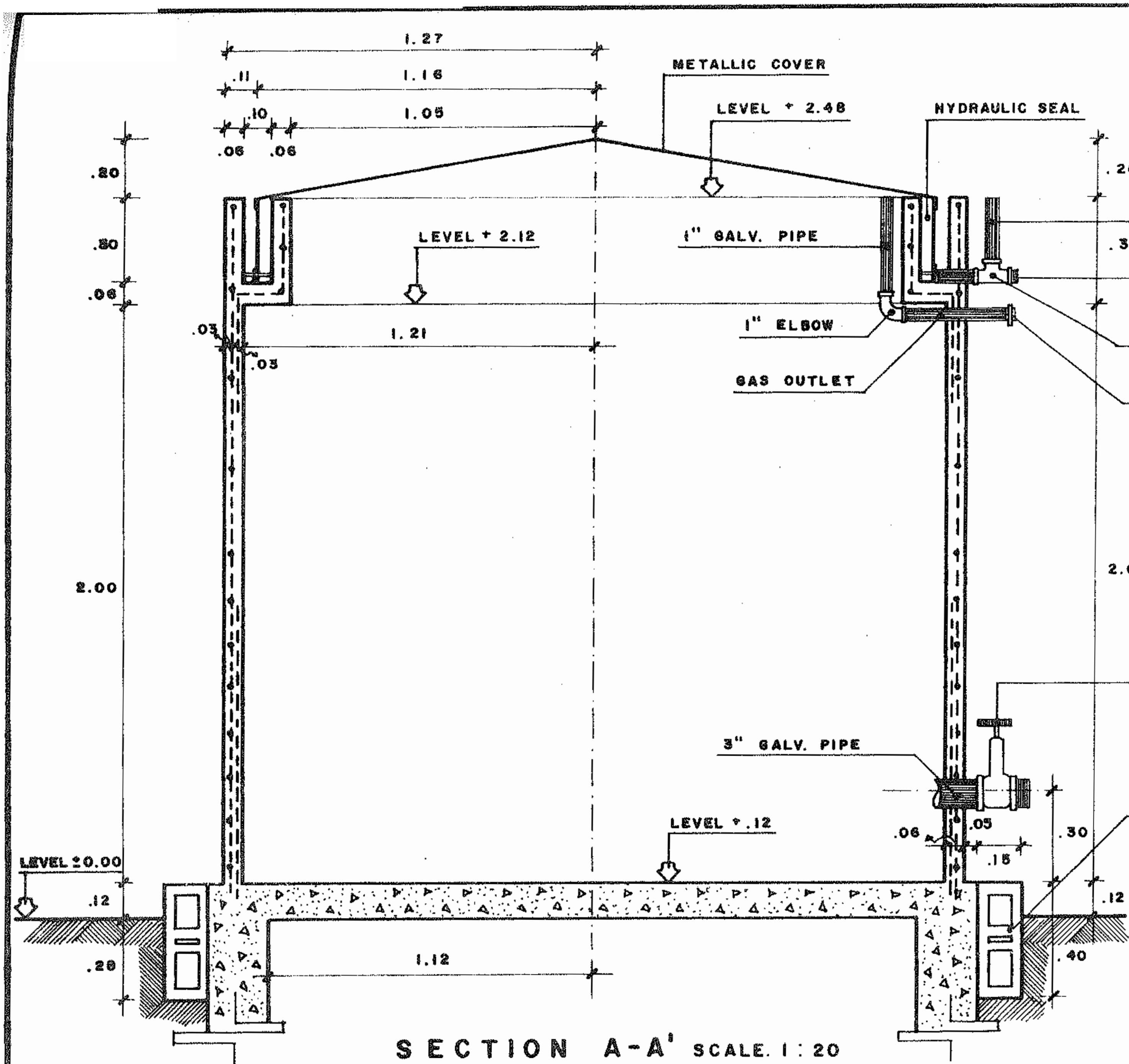
| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 1 | contains: PLANT-DETAIL | scale: INDICATED |
| | capacity: EACH DIG. : 9 M3 | type: OLADE-GUATEMALA |




SECTION A-A' SCALE. 1 : 20

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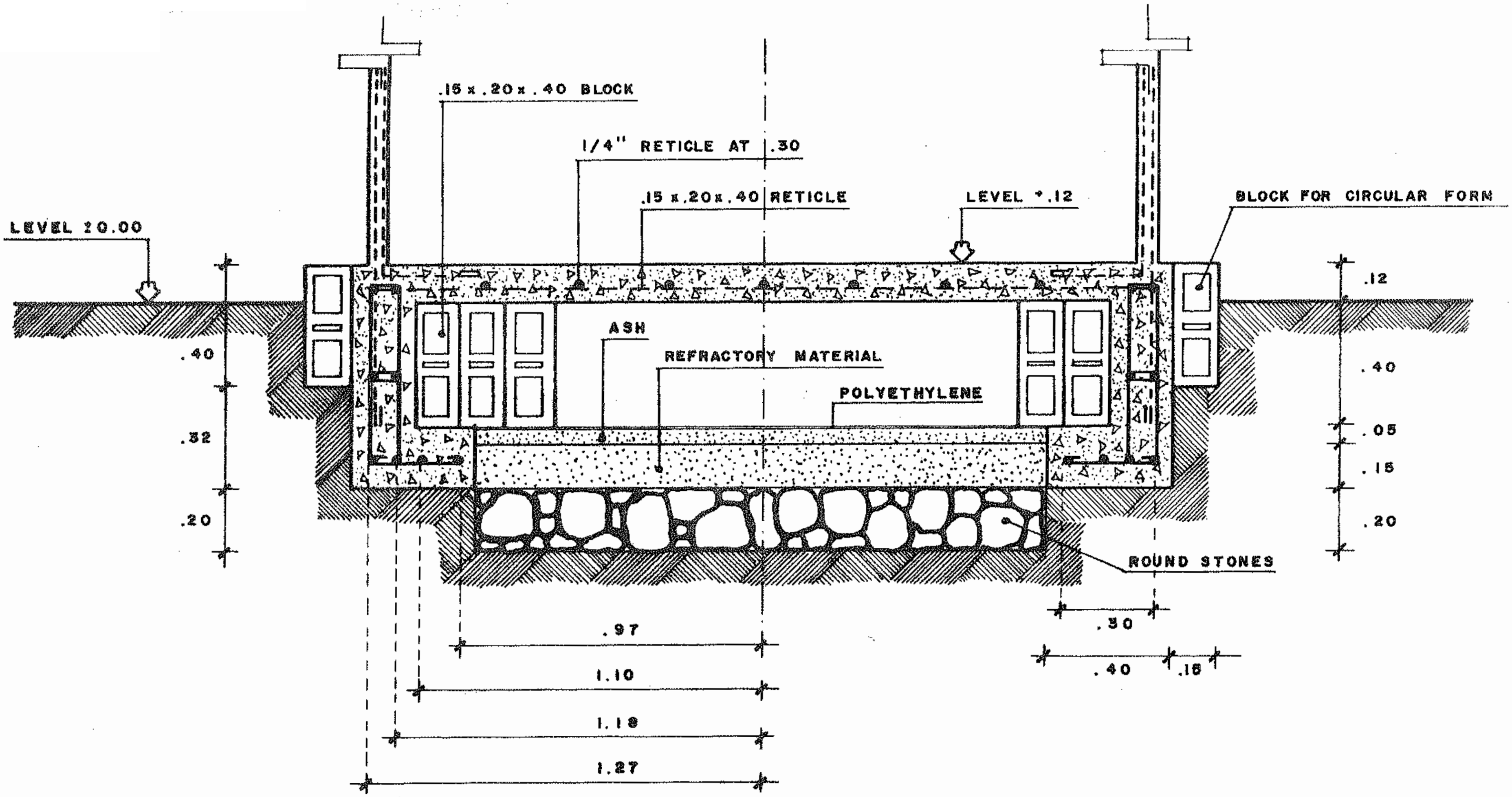
project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: | scale: |
|---|---|---|
| 2 | SECTION | INDICATED |
| | capacity: EACH DIG.: 9 M3 | type: OLADE-GUATEMALA |



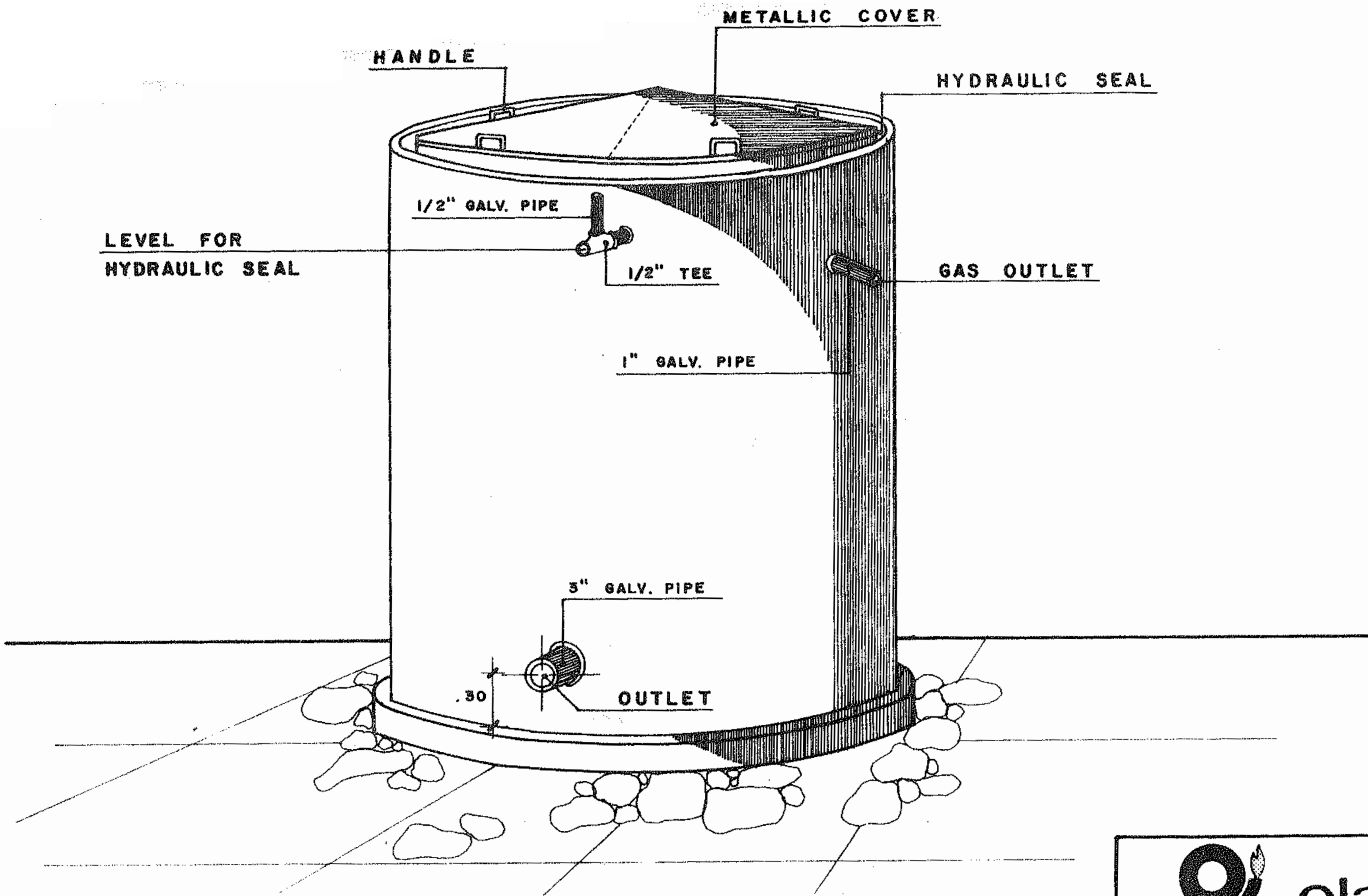

SECTION A-A' SCALE. 1:20

(CONTINUATION)

olade

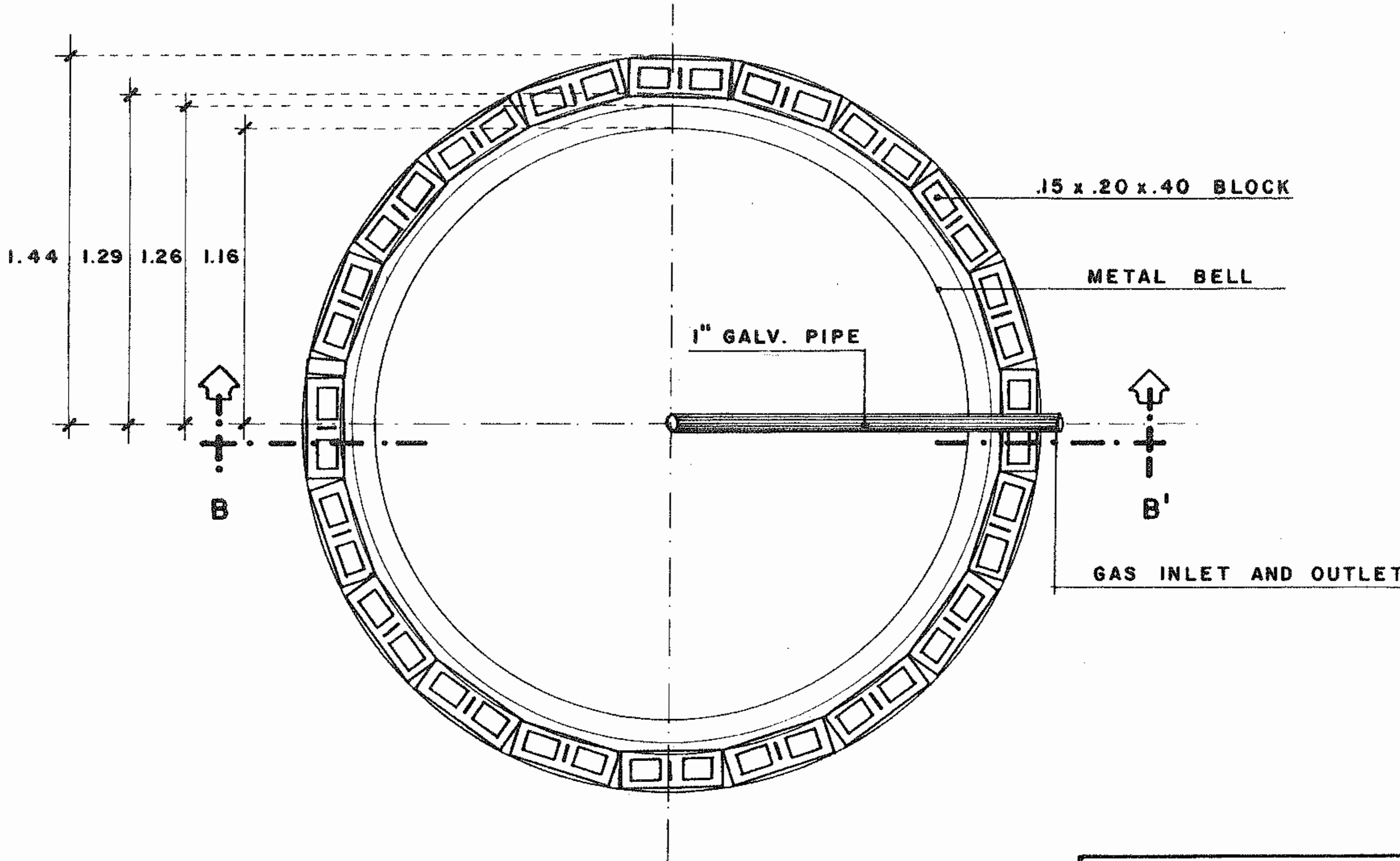
project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: | scale: |
|---|---|---|
| 3 | SECTION | INDICATED |
| | capacity: EACH DIG. : 9 M3 | type: OLADE-GUATEMALA |




DIGESTER PERSPECTIVE

| | | |
|---|---|---|
| olade | | |
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 4 | contains: PERSPECTIVE | scale: |
| | capacity: EACH DIG. : 9 M3 | type: OLADE-GUATEMALA |



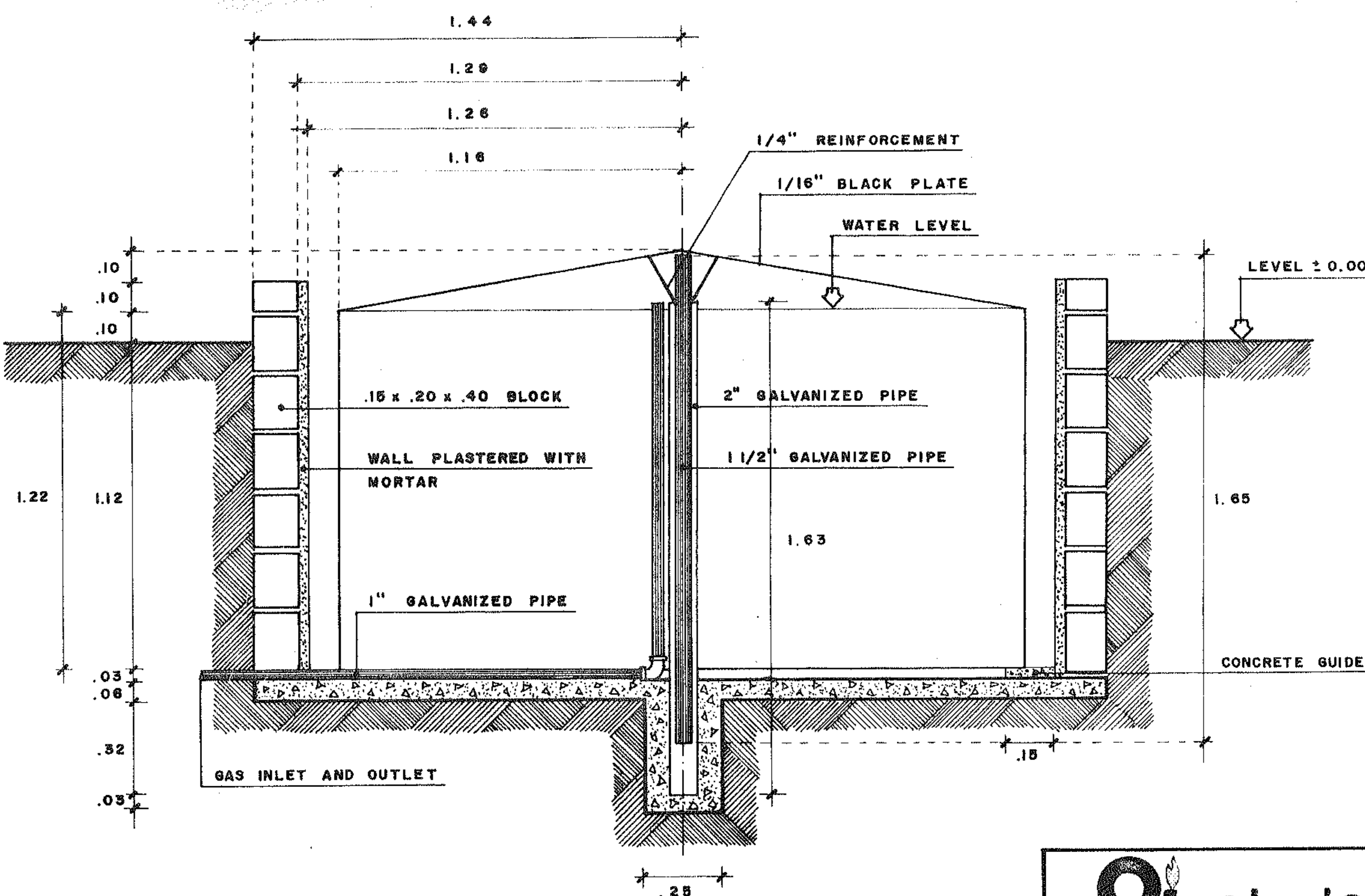

GENERAL PLANT SCALE. 1 : 25

(VIEW OF SINK WITH BELL)

GASOMETER

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 5 | contains: PLANT | scale: INDICATED |
| | capacity: 5 M3 GASOMETER | type: OLADE-GUATEMALA |



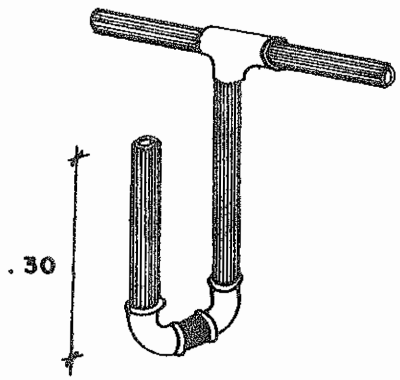

SECTION B-B' SCALE. 1: 20

olade

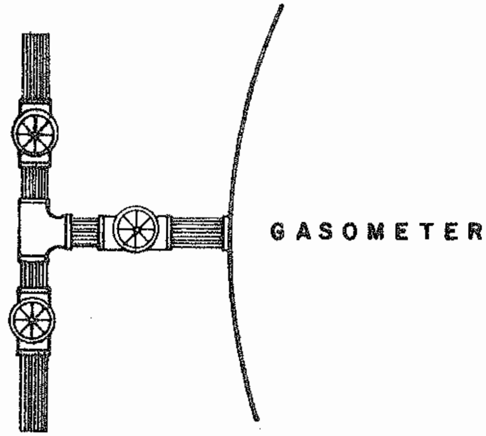
project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: | scale: |
|---|---|---|
| 6 | SECTION | INDICATED |
| | capacity: 5 M3 GASOMETER | type: OLADE-GUATEMALA |

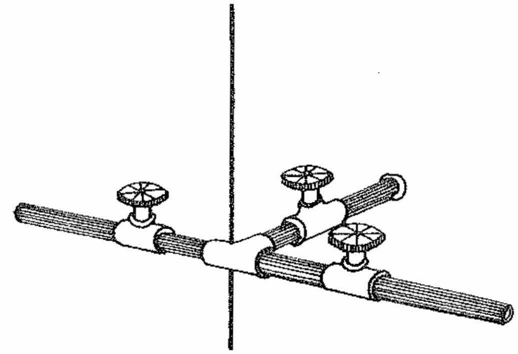
PERSPECTIVE




DETAIL OF CONDENSATION WATER TRAP

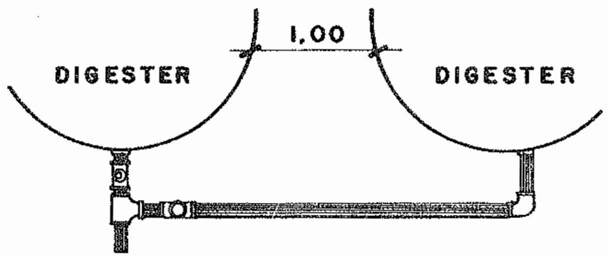



PLANT

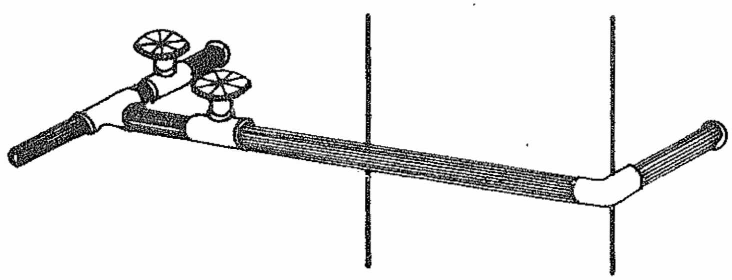


PERSPECTIVE

PIPING DETAIL (GASOMETER ACCESS)

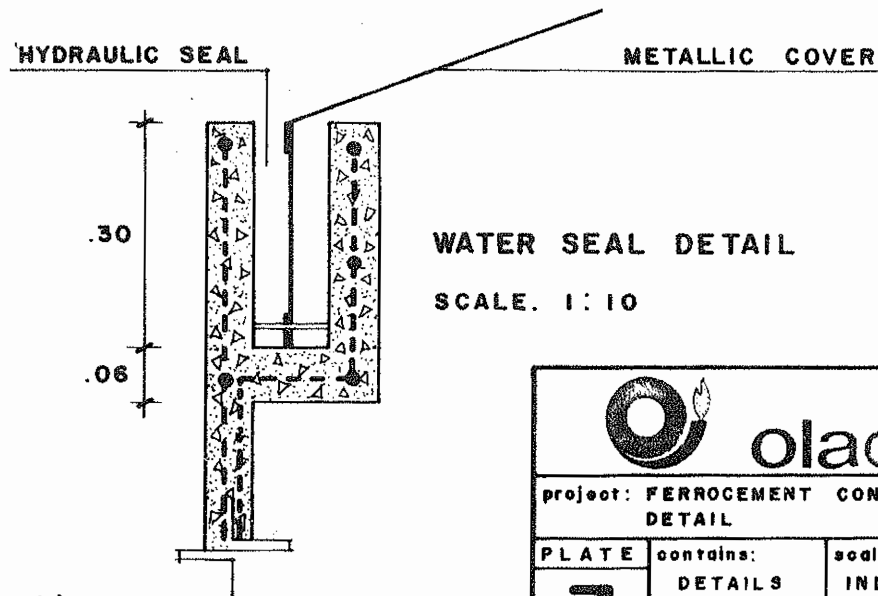



PLANT



PERSPECTIVE

PIPING DETAIL (INTERCONNECTION BETWEEN DIGESTERS)




WATER SEAL DETAIL

SCALE. 1:10

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 7 | contains: DETAILS | scale: INDICATED |
| | capacity: | type: OLADE-GUATEMALA |

The required compaction permits the elimination of air bubbles that may remain inside and at the same time increases the digester's capacity for receiving solids.

Once filled, the digester is saturated with water (or preferably, with residual liquid from previous loads) to a level some 10 cm. above the level of solids.

It is also important to mention that before sealing the digester, one should wait for the water to seep into the material, in order to avoid unexpected drops in the level of water situation which is quite undesirable.

After this, the digester is closed and hermetically sealed, with water added to the respective seal. The digestion process now begins.

Under favorable environmental conditions, the production of gas fuel is noted between 4—1- days after the sealing of the digester.

The period of digestion, given adequate mixtures and suitable climatic conditions, can take approximately 35—45 days, with useful outputs of gas.

On observing a decrease in gas production (when this reaches levels which are not very useful), it is time to begin the discharge process.

The gas outlet valve on this digester should be closed, and the water seal should be emptied. After this, the digester should be uncovered and the drain—pipe opened to allow the liquid bio—fertilizer to scape, leaving it to drain completely; this process takes approximately 48 hours. At the end of this process the solid fertilizer is extracted and the digester is cleaned, so as to be ready to be loaded once again.

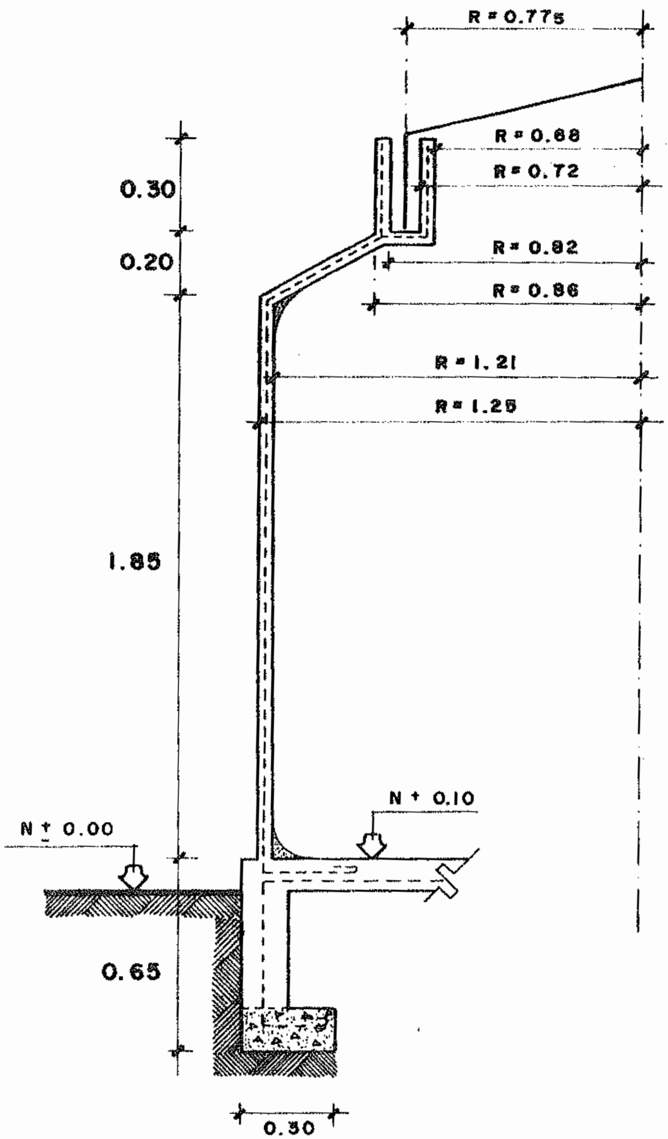
### 1.6 UTILIZATION OF THE DIGESTER PRODUCTS

The most important objective of this technology is the production of a large quantity of bio—fertilizer with high organic content, which is very reliable for the reduction of eggs and other elements harmful for human as well as for the soil. To demonstrate this, the example of the plant described above can be used: its volumen of production corresponds to six tons of solid bio—fertilizer, and 4 $m^3$ of liquid bio—fertilizer, in every discharge, and a maximum daily biogas production of 10 $m^3$ (depending on the conditions of the mixture and the environment).

### 1.7 OTHER MODELS FOR DIGESTERS

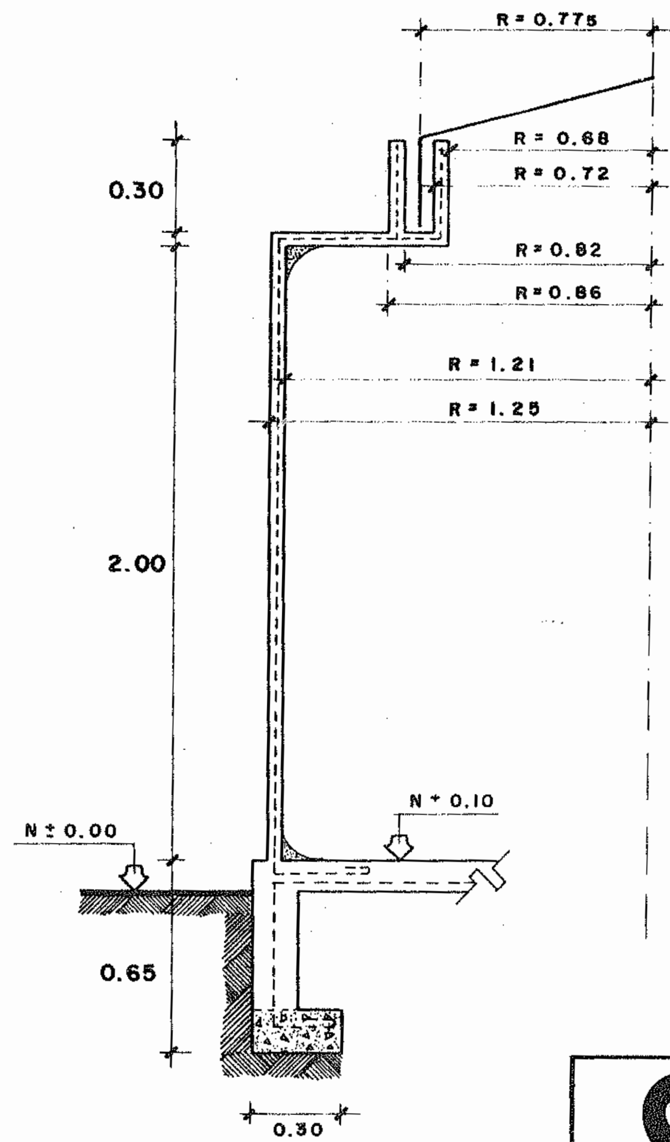
The design of the digester with a metal tap of the same size as the diameter of the cylinder can be changed by taps of smaller diameter and cost. Their size will depend on the easiness of unloading the digester from inside, by suing a shovel.

Chart No. 8 shows in detail this model of digester. The material needed for this digester has small changes in regards to quantities. The material and cost of the metal tap is reduced enough. In the chart one can see designs A and B for both types of reduction of the neck that have been recommended.




**DESIGN A**

SCALE. 1:25



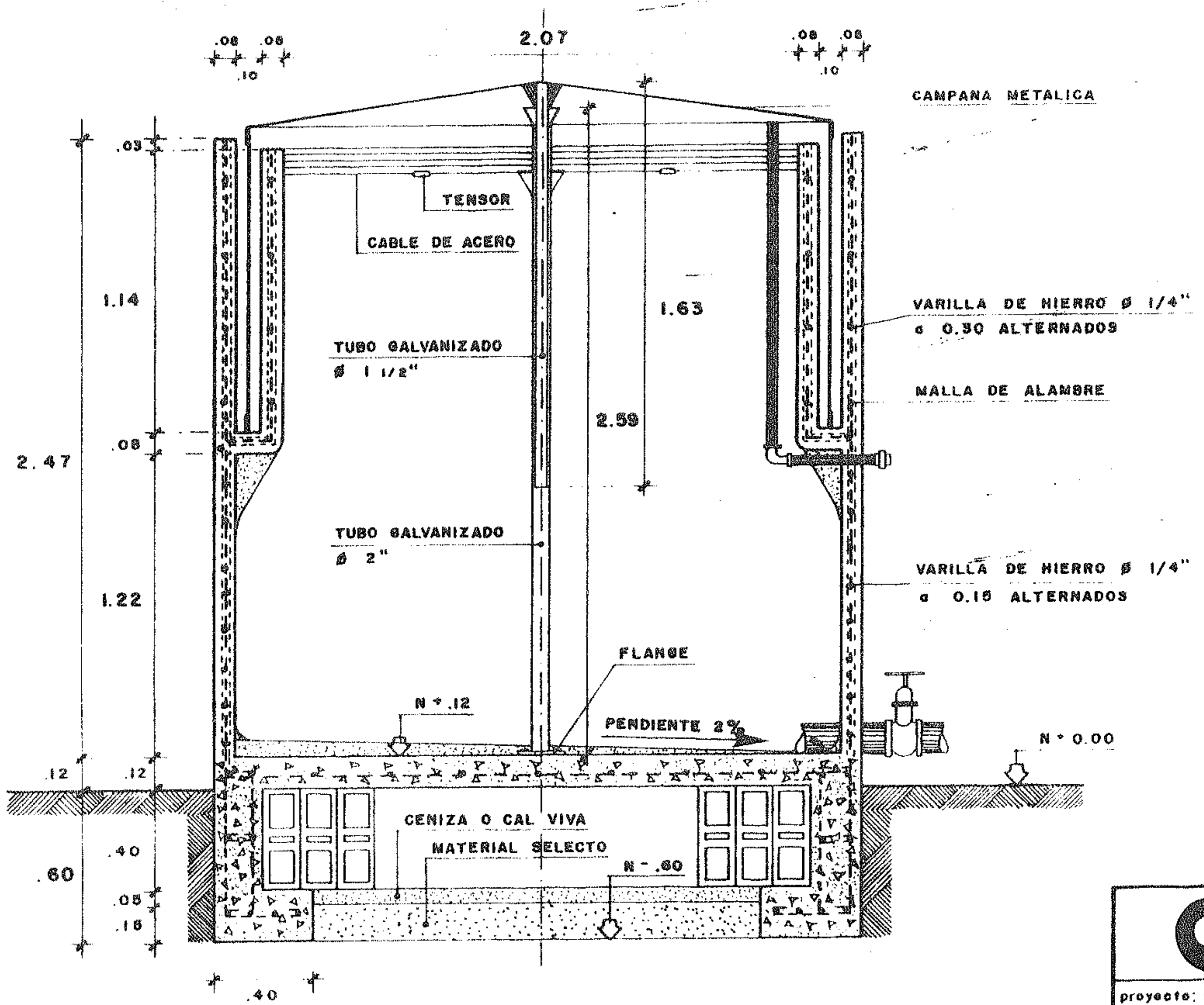

**DESIGN B**

SCALE. 1:25

olade

project: MODIFICATION ACCESS MOUTH IN FERROCEMENT

| | | |
|---|---|---|
| PLATE | contains: DETAILS | scale: INDICATED |
| 8 | capacity: 9 $M^3$ | type: OLADE-GUATEMA |




CORTE ESCALA 1:25

olade

proyecto: MODIFICACION CON GASOMETRO INCORPORADO SOBRE DIGESTOR

| LAMINA | contiene: | escala: |
|---|---|---|
| 9 | CORTE | INDICADA |
| | capacidad: 9 M3 | tipo: OLADE-GUATEMALA |

## 2. DIGESTER: THE CHINESE TYPE

### 2.1 BASIC DESIGN

The Chinese—type anaerobic digester uses semi—continuous operation and has the following design characteristics:

a. There are no movable parts
b. Circular section, vertical axis: cylindrical walls
c. Flat: small height/diameter ratio
d. Dome—shaped roof and floor: spherical sections
e. Underground construction: buried
f. Lateral intake and outlet chambers: diametrically opposed
g. Removable cover in the upper part of the dome with an opening for the gas outlet pipe

The combination of these characteristics creates a highly resistant structure which uses fewer construction materiales for a given internal volume and which can be constructed with local materials at reduced costs.

The demand for biogas and fertilizer, along with the available organic waste material, will determine the capacity of the Chinese—type digester to be constructed. It is particularly adaptable to family sizes (internal volumes of 6, 8, 10 or 12 $m^3$) although the community sizes (internal volumes of 50, 100 or 200 $m^3$) have been widely accepted. This design can be adapted to varied climates, including temperate and cold ones, because of its great capacity for thermal insulation, which reduces the effect of temperature variations between the seasons and between day and night.

The gas storage takes place inside, in a free space determined for that end.

### 2.2 CONSTRUCTION MATERIALS

The digester can be constructed with diverse materials, depending on the nature of the terrain, the freatic level and available local materials:

a. prefabricated concrete blocks and mortar
b. Baked clay bricks and mortar
c. bricks made of "puzzolanic cement" (lime—puzzola)
d. boulders and mortar
e. ordinary concrete (cement, sand, gravel)
f. directpit excavation in rocky terrain

Digesters, of 50 $m^3$ or larger, also require quarter—inch thick iron rods (wire) to strengthen the dome—wall joint ring. They also require pre—fabricated concrete piping, 25—30 cm. in diameter, for the inlet pipe and the joint between the fermentation chamber and the effluent outlet.

## CONSTRUCTION MATERIALS USED IN THE CHINESE–TYPE BIOGAS PLANT 12 $m^3$ WITH BRICK TECHNIQUE

| MATERIALS | QUANTITY |
|---|---|
| 1. Bricks 2 x 4 x 8" | 1.300 units |
| 2. Portland cement (45 kg. bags) | 29 units |
| 3. Lime (22 kg. bags) | 22 " |
| 4. Sand (fine grain) | 4 $m^3$ |
| 5. Gravel of 1/2" | 2 $m^3$ |
| 6. Cement pipes 10" x 3' | 2 units |
| 7. Cement pipes 8" x 3' | 1 unit |
| 8. Boards 1 x 4" x 10' | 3 units |
| 9. Boards 4 x 6" x 12' | 2 " |
| 10. Water proofing agent | 20 kg. |
| 11. PVC pipes of 1/2" | 10 ft. |
| 12. PVC pipes of 1 1/2" | 18 ft. |
| 13. PVC pipes of 2" | 3 1/2' |
| 14. Chain of 1/8" | 3 1/4" |
| 15. Playwood sheets | 1 unit |
| 16. Stopcock 1.2" | 1 " |
| 17. Cooper tubing of 1.2" | 4 ft. |
| 18. Galvanized tee of 1/2" (union) | 1 unit |
| 19. Fittings (ring–mounthed reduction couplers) | 5 units |
| 20. Hose of 1/2" | 50 ft. |
| 21. Trail rope | 8 pounds |
| 22. Plastic kegs | 3 units |
| 23. Clamps of electric wiring of wall | 10 units |
| 24. Joint sealing tube (permatex) | 1 unit |
| 25. Wire mesh of 1/4" x 12 m. | 2 units |

### 2.3 CONSTRUCTION TECHNIQUES

We will refer to only three of them:

#### a. Construction with Pre–fabricated Blocks

In the first place, the pre–fabricated concrete blocks are fabricated manually or semi–industrially using molds suited to the size of the digester and each of its parts (wall–dome). Then an excavation is made for the wall, until its proportions are those of the desired diameter and depth, plus an extra space around it which will later be filled with compacted earth. After putting regular–sized boulders on the earth floor, which was previously compacted, concrete is poured to form the base of the digester, making use of special wooden framing for each size. Immediately afterwards, a cylindrical wall is put up, row by row, filling in the extra space with well–compacted earth. Once the required height is reached, a ring of blocks is constructed to support the dome; the circular wedge will be filled with mortar (in the case of community digesters, this wedge will be reinforced with 1/4" iron rods). The dome construction can be made with a bamboo form and woven straw mats or partically without the mold, but using iron clamps for support. This type of construction is the fastest and is recommended for terrain that has a relatively high freatic level.

### b. Construction with Bricks.

Construction is similar to the previous case, up to the pouring of the floor; then the wall is constructed with four rows of bricks (in the case of the family—size digester). The support ring for the dome is similar to the previous case, except that it is made with bricks, and the dome is constructed without the need for a grame, using iron clamps for support. This, being the simplest technique, is slow and is recommended for terrain that has a low freatic level.

### c. Construction with Premixed Concrete Using an Earthen Frame

First, the land is marked out with lime by means of a projection from the upper plane of the digester. Next, a hole approximately 60 cm. in diameter, and 2 meters deep at its central axis, is excavated. Then, a partial excavation of the earth is made until it reaches a depth profile exactly equal to the inner part of the dome, this being achieved by shaping the land with the help of special molds. Afterwards, excavation of a circular trench is made, sufficiently thick and deep to form the frame of the wall with earth. Concrete is poured into the trench in 20 cm layers, compressing frequently in order to eliminate air and water until the wall is completed. Then, concrete is poured on the earthen dome following the thickness of mold and proceeding radially to complete the dome. As soon as the dome and the wall are formed, and this takes a minimum of eight days, a mason goes into the central opening and gradually removes the earth from the middle in a circular manner from top to bottom, until he reaches the desired depth; pours in concrete, with the help of another special mold. The material taken out is used as filler spread over the dome.

This construction techniques requires special skill, which, once acquired, allows for the bulding of the most economical digesters, in terms of economy of materials and labor. It is recommended for consistent soils and low freatic levels.

### d. Notes on Construction Techniques

—The collar or mouth of the dome is always constructed with a frame made of wood or another material.

—The inlet pipe and that which unites the tank and outlet chamber are always installed before the wall is completed and before the dome is constructed.

—The intake and outlet chambers are contructed from bricks, blocks, or molded concrete.

—The digesters made of bricks and blocks require 6 internal coats of plaster, as a sealing agent to prevent leakage. The digesters of molded concrete need only one coat of mortar mixed with sodium silicate.

—Place a compact layer of stone, before forging the base (to have a 90 o/o protection) then place a small bed of stones, with a thickness of some 0.10 to 0.15 cm. Wet the ground with the compaction.

—The bricks to be utilized must be wet (by immersion) two days before, but at the moment of use must be superficially dry.

—Lime paste: 3 days before use, put lime in 30—40 o/o water and grind; 24 hours later, sift it through 1 mm. mesh. Protect with plastic from excesses of water and sun.

—The slope of the base of the upper dome is extended (with string), with the radius to the last brick of the cylinder.

—The tube to the inlet chamber should be covered with 3 applications of pure cement paste, to be brushed on.

—The first two rows of the collar should be formed from brick halves, placed vertically.

—To determine the shell form, use: 1 central axis and a cord to mark the radius of the shell or of the cylinder (with a level).

—The size of the sand particle has to be smaller than 0.35 mm.

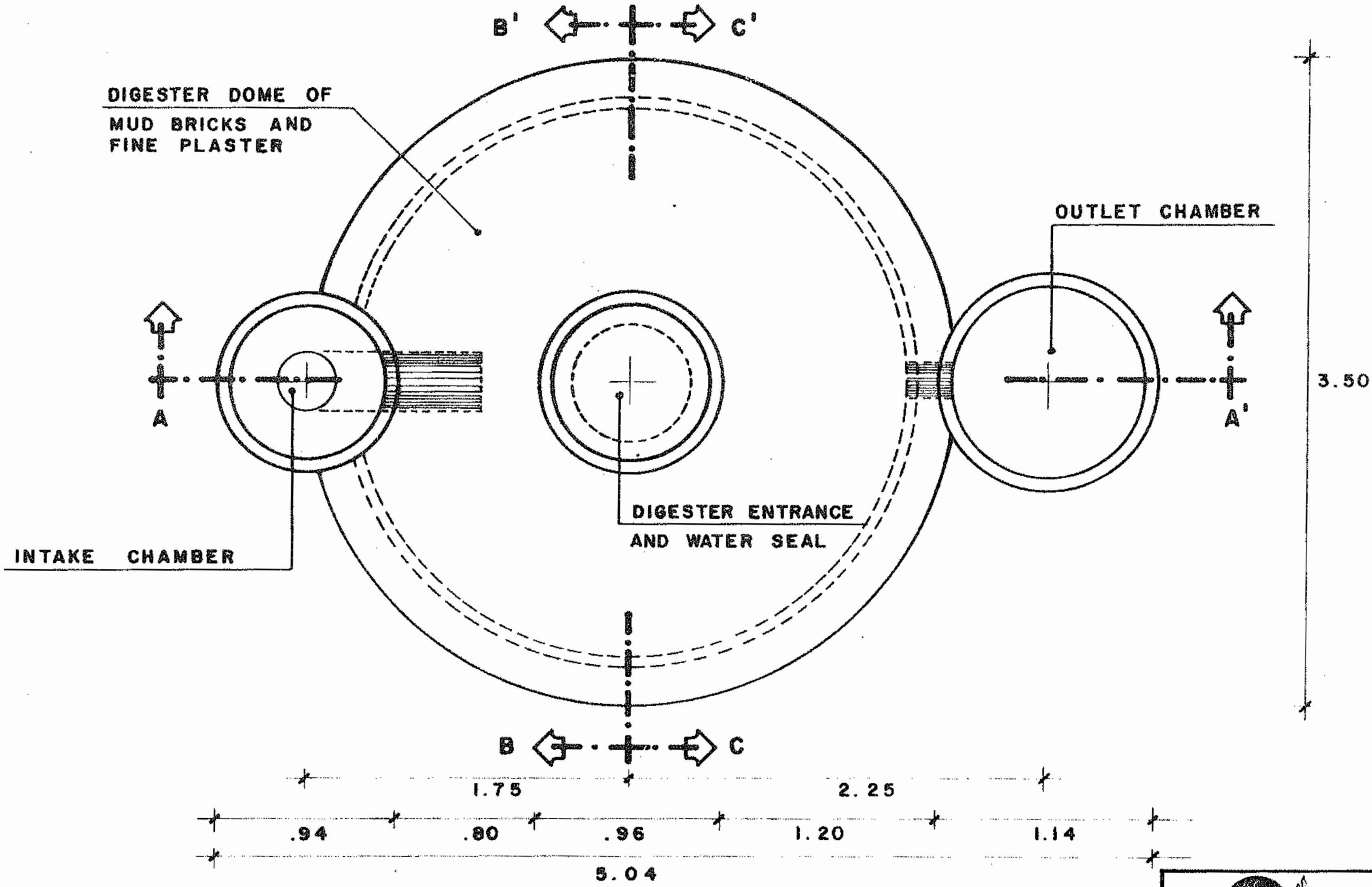
—The inside face of each brick must be in strong, direct contact with the next brick. Fill the rest completely with mortar mix and with some little stone pieces, to obtain better pressure.

**PROPORTIONAL CHART OF MIXTURES AND MORTARS**

| Mixture | | Thickness | Cement | Lime | Lime Paste | Coal Ashes | Regular Sand | Fine Sand | Clay Paste | Sodium Silicate | Ferrous Chloride | Calcicum Chloride |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base | | 6 cm | 1/2 | 1 | | | 3 | | | | 2 o/o | |
| Mortar | | 2 cm | 1 | | 1.5 | | 5.5 | | | | 2 o/o | |
| Whitewash | | | 1 | 3 | | | 4 | | | | | |
| Internal Whitewash | 1 | 5 mm | 1 | | | | | | | 20 o/o | 2 o/o | |
| | 2 | 7 mm | | | 1 | 2 | | 3 | | | | |
| | 3 | 5 mm | 1 | | 1 | | | | | | 2 o/o | |
| | 4 | 4 mm | 1 | | 1 | 2 | | 2 | 3 | | 2 o/o | |
| | 5 | 5 mm | 1 | | | | | | | 20 o/o | 2 o/o | |
| | 6 | film | 1 | | | | | | | | 2 o/o | 20 o/o |

## 2.4 RAW MATERIALS FOR DIGESTERS

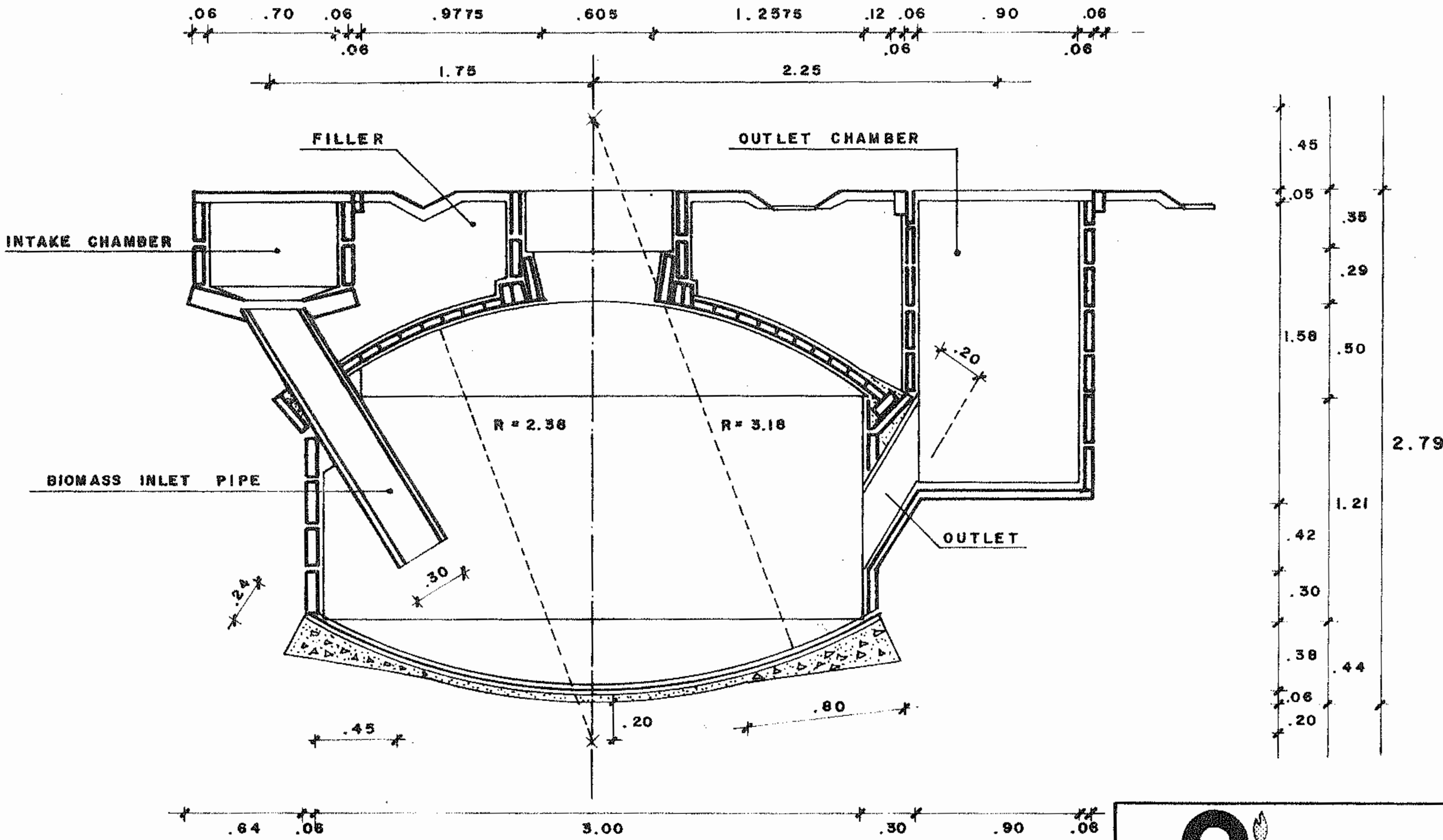
The Chinese—type digester uses all types of agricultural waste, including human excretion, while it is always recommended that a mixture of materials be used. The Chinese operation techniques permit the digestion of cellulose material, e.g., grain residues, grass, leaves, etc., as long as the digester is loaded with material that has been aerobically pre—composted. The techniques of pre—compost is described in a subsequent diagram. It is important to emphasize that a large degree of the success of the Chinese biogas technology depends on pre—compost, and the following advantage are to be derived:




GENERAL PLANT SCALE. 1 : 33 1/3

olade

| project: BIO-GAS DIGESTER WITH MUD BRICKS | | |
|---|---|---|
| PLATE | contains: PLANT | scale: INDICATED |
| 1 | capacity: 12 M3 | type: CHINESE |

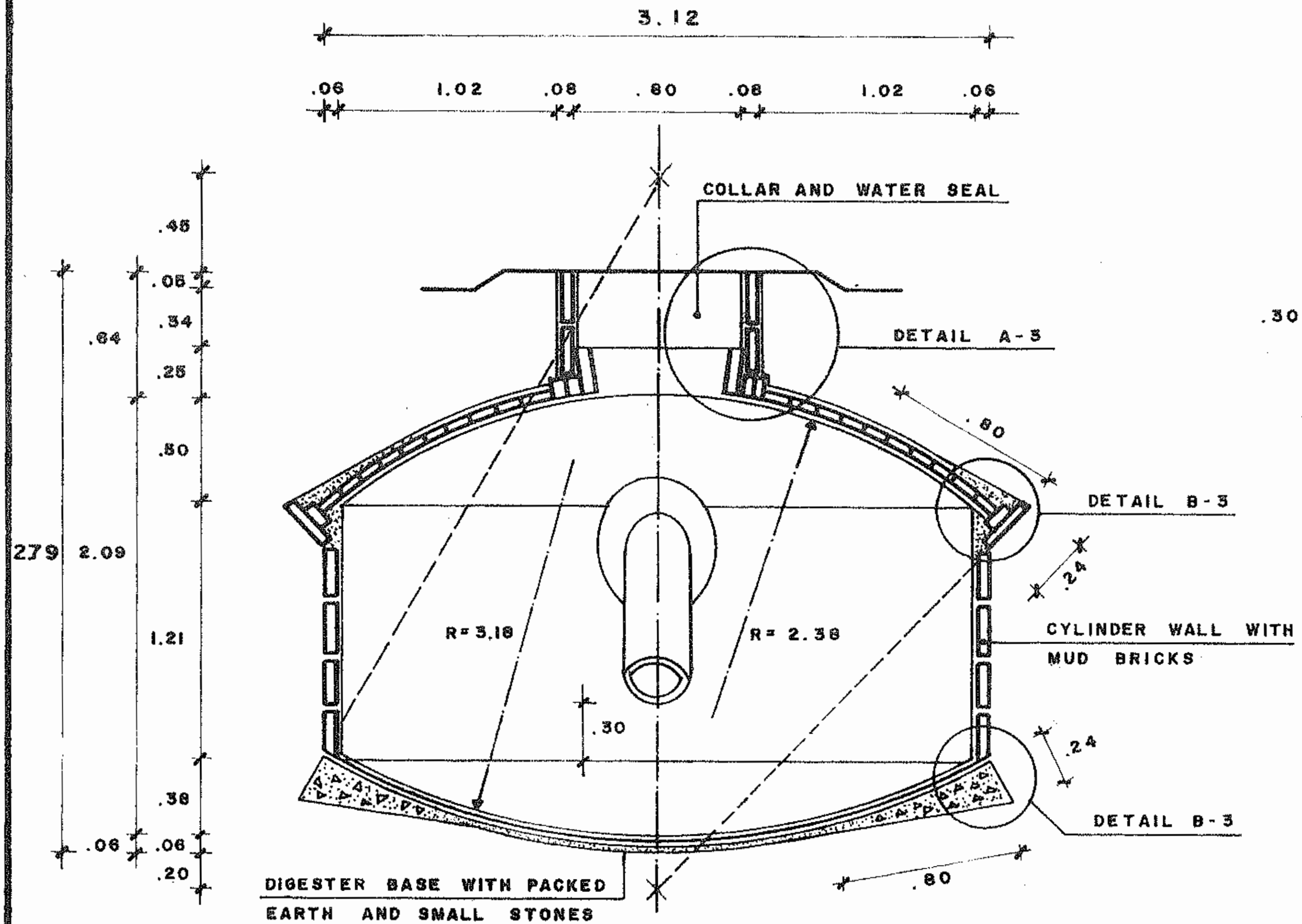



SECTION A–A' SCALE. 1:33 1/3

olade

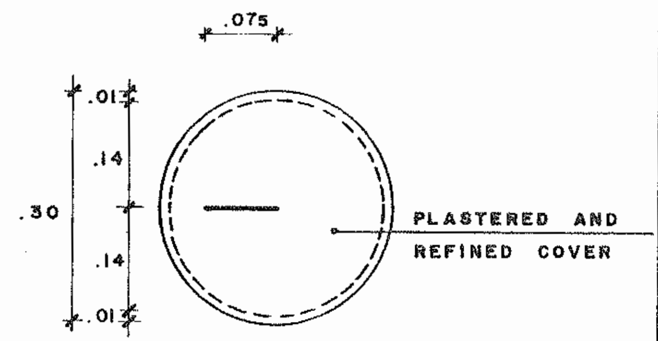
project: BIO-GAS DIGESTER IN MUD BRICKS

| PLATE | contains: | scale: |
|---|---|---|
| 2 | SECTION | INDICATED |
| | capacity: 12 M3 | type: CHINESE |

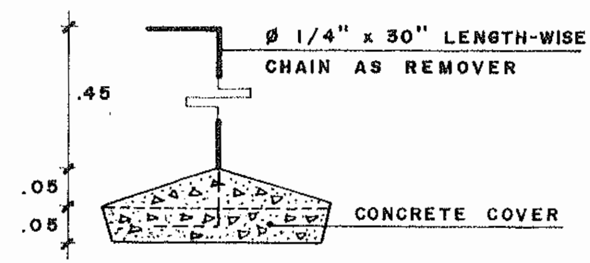



SECTION B-B' SCALE. 1:33 1/3

## COVER DETAIL




PLANT SCALE. 1:10

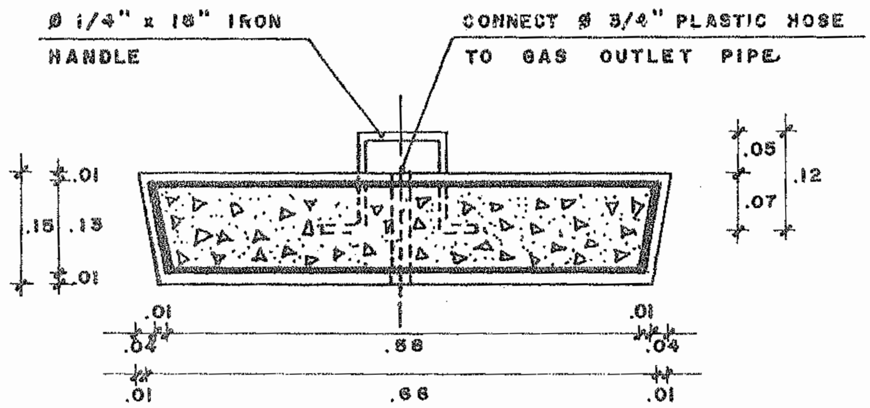



ELEVATION SCALE. 1:10

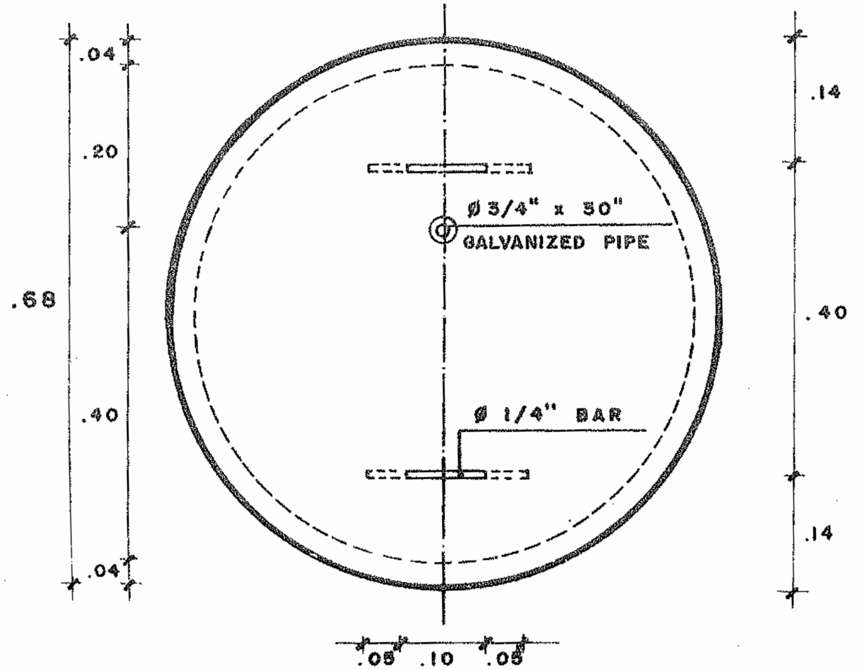
olade

| | | |
|---|---|---|
| project: BIO-GAS DIGESTER WITH MUD BRICKS | | |
| PLATE | contains: SECTION-DETAILS | scale: INDICATED |
| 3 | capacity: 12 M3 | type: CHINESE |

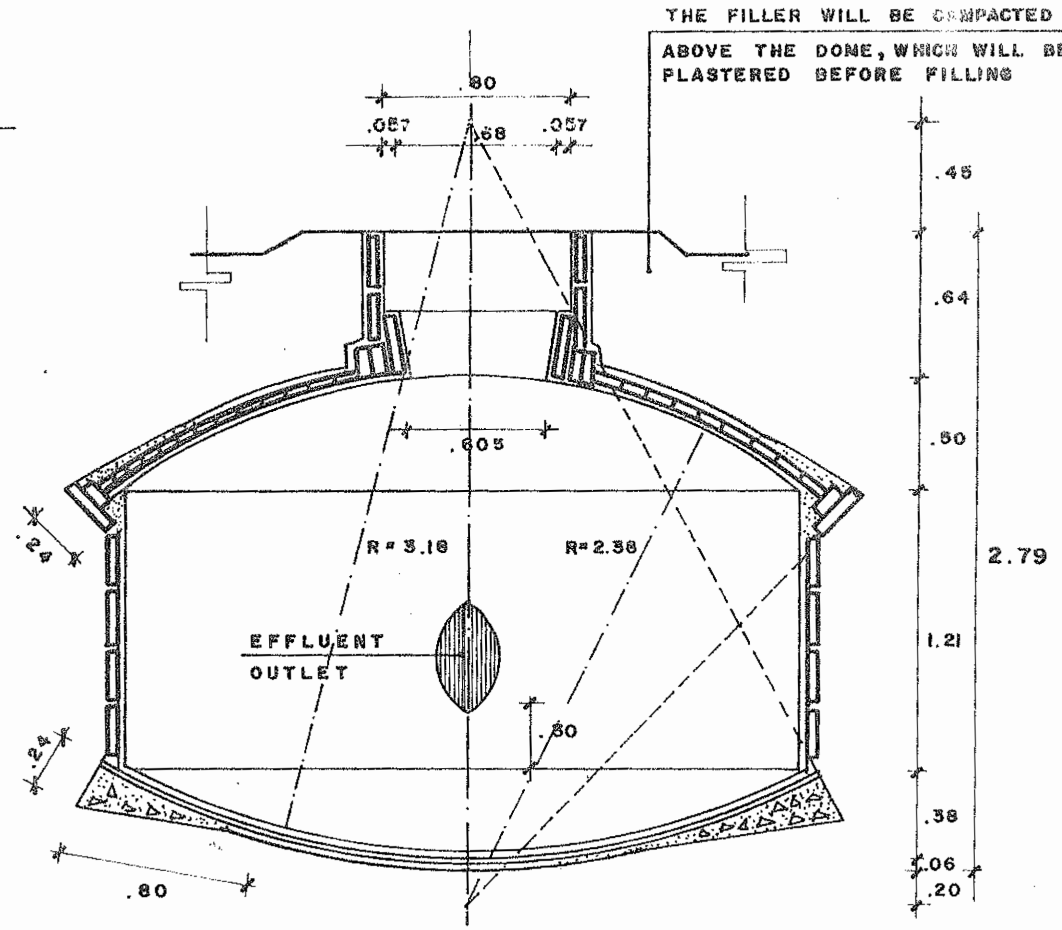
# COVER DETAIL




ELEVATION SCALE. 1:10

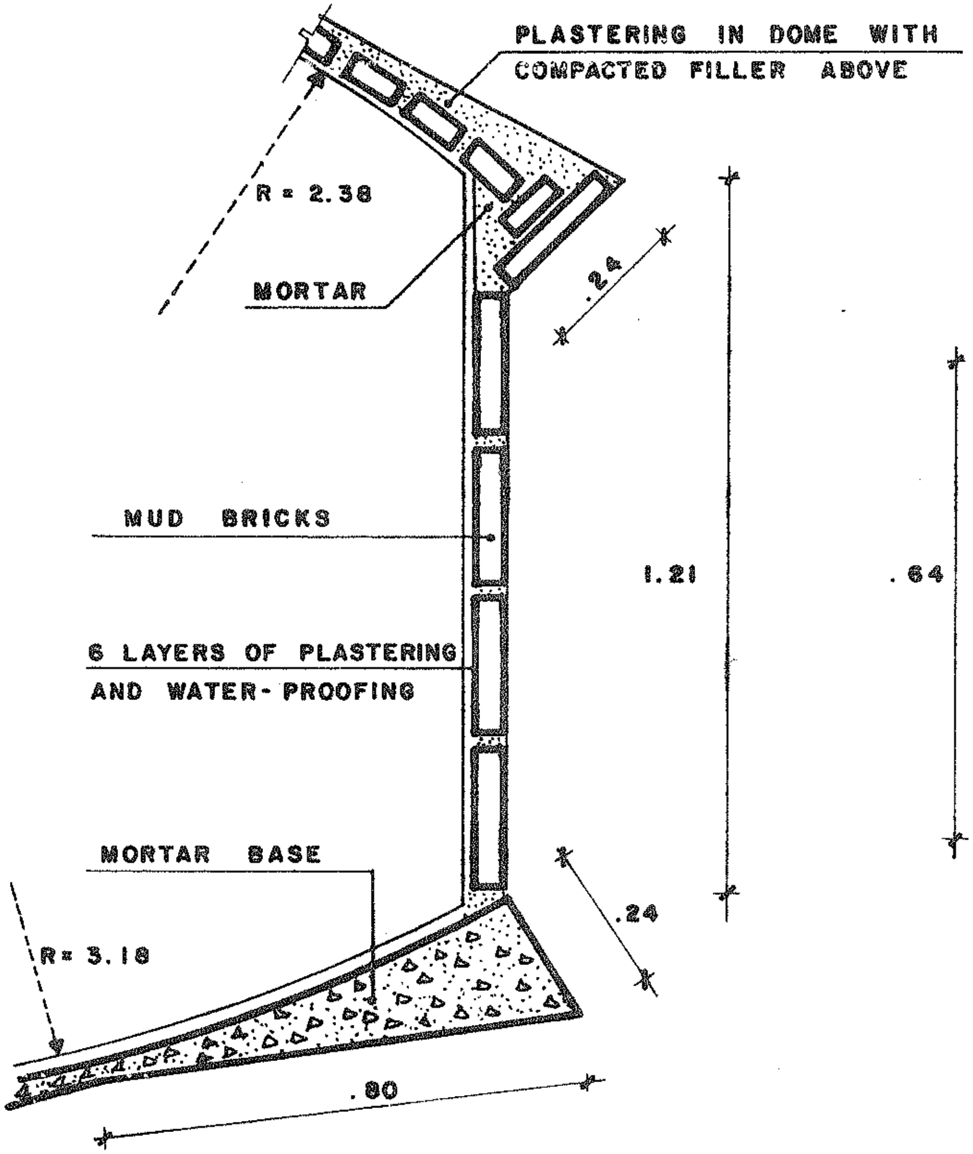



PLANT SCALE. 1:10



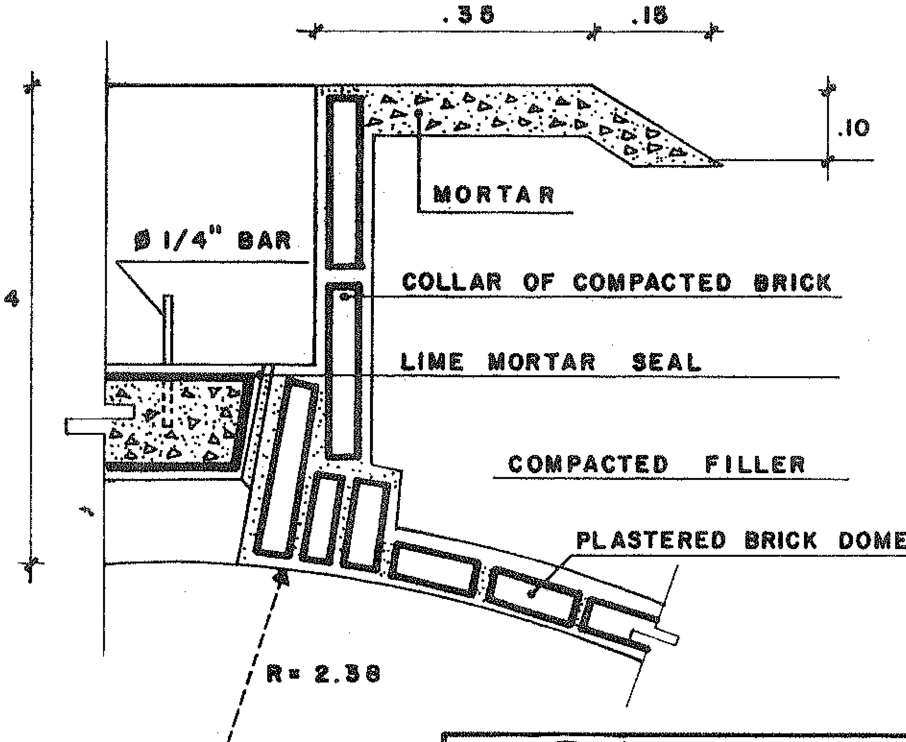

SECTION C-C' SCALE. 1:33 1/3

| | | |
|---|---|---|
| olade | | |
| project: BIO-GAS DIGESTER WITH MUD BRICKS | | |
| PLATE | contains: SECTION-DETAIL | scale: INDICATED |
| 4 | capacity: 12 M3 | type: CHINESE |




DETAIL B - 3 SCALE. 1:10

DETAIL A- 3 SCALE. 1:10




olade

project: BIO-GAS DIGESTER IN MUD BRICKS

| PLATE | contains: | scale: |
|---|---|---|
| 5 | DETAILS | INDICATED |
| | capacity: 12 M3 | type: CHINESE |

a. adequate temperature for the multiplication of aerobic and anaerobic bacteria.

b. generation of heat (60—70$^{o}$C) that removes the waxy coating of the straw and permits partial cellulose and lignine breakdown until their homogeneous disintegration in the digesting liquid, avoiding the formation of foamy scum.

c. heat that is responsible for destroying the majority of parasites which are initially present.

d. heat that raises the temperature of the initial solution of the loas.

e. partial degrading of the initial raw material, which accelerates the production of biogas fuel.

f. obtaining of more homogenous and accessible effluents and sludge. Moreover, it is very important to add different types of inoculores in the initial load, up to a volume of 10 o/o of the total volume of liquid.

### 2.5 DIGESTER OPERATION

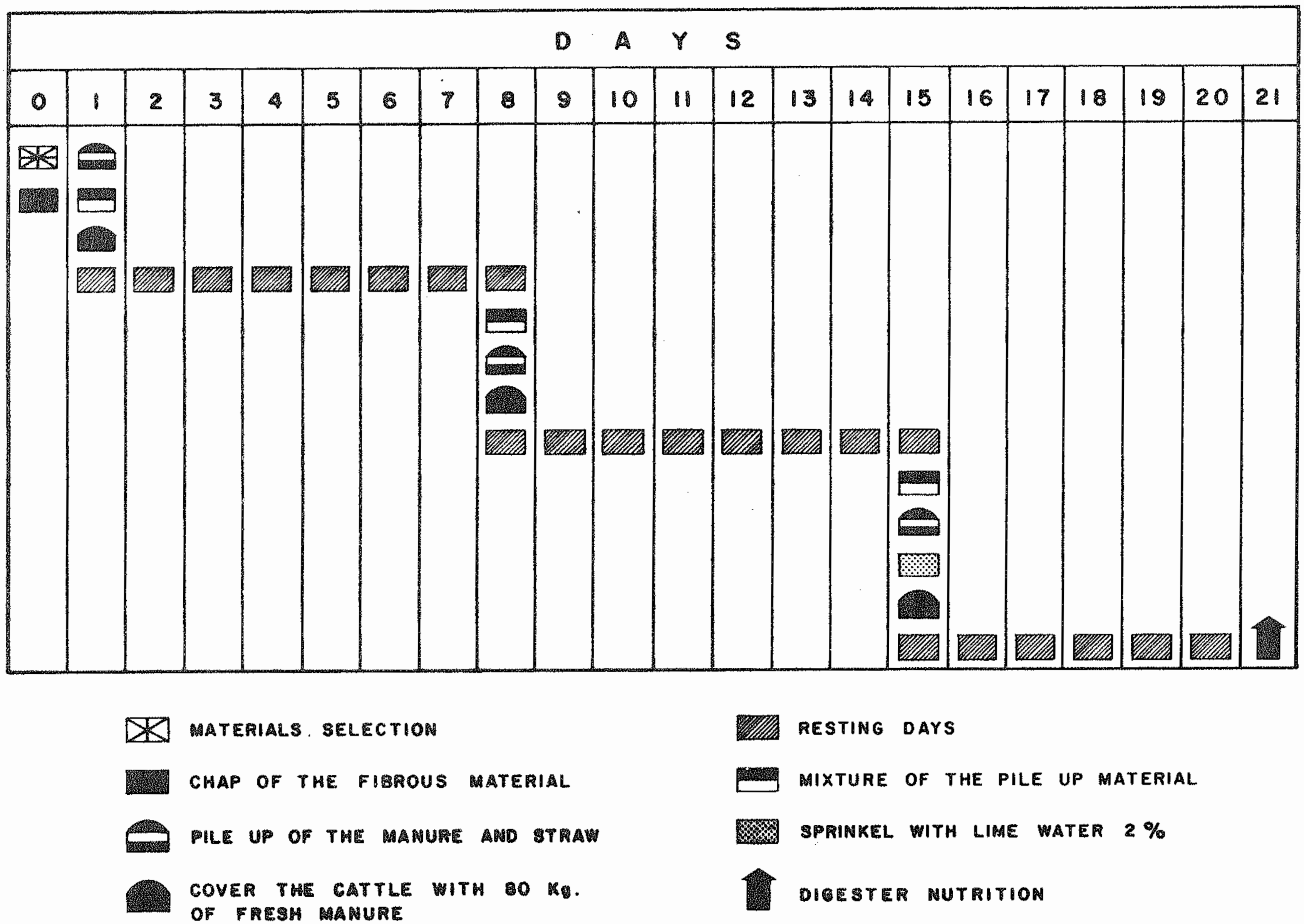
The Chinese—type digester functions on a semi—continous basis. It is initially loaded with pre—composted material at a concentration level of 7—5 o/o of the total of solids in suspension and, then it is reloaded periodically (daily, every other day, or weekly) with raw materials, preferably precomposted, in a quantity equivalent to the gas produced. It is recommended that the liquid effluent be recirculated frequently.

### 2.6 UTILIZATION OF DIGESTER PRODUCTS

The gas is carried by plastic pipes directly to stoves, lamps, motors, and other combustion devices. This design does not allow the user to obtain biogas at a constant pressure; thus, it is recommended that the consumption of this gas be regular, in order to avoid great fluctuations in the pressure.

The effluent should be collected simultaneously with the periodic loading, to be used in agriculture livestock activities or for aquaculture. Every 6 months, more or less, the Chinese digester should be emptied to collect the sedimentary sludge and liquid effluent, leaving a tenth of the initial volume of the latter in the digester, as an innoculator for the new load.

## PREFERMENTATION CHRONOGRAM



## KNOWN LATINAMERICAN EXPERIMENTS WITH CHINESE TYPE DIGESTERS WITH DOMES, AS OF JUNE 1980

| AVAILABLE INFORMATION | COLOMBIA | JAMAICA | GUATEMALA ** | PERU |
|---|---|---|---|---|
| Entity | "Providence" Experi– mental Farm | Scientific Rearch Council | CEMAT | ITINTEC |
| Person in charge | J. Correa Bulla | K.C. Lee | R. Cáceres | J. Verastegui |
| Number of digesters | 1 | under construction | 9 | 3 |
| Size of digester ($m^3$) | 12 | 67 | 12 | 10 |
| Location | Bogotá | Kingston | Plateau | Plateau |
| Environmental temperature | 12–27 | 22–28 | 10–22 | 10–18 |
| Altitude (m/sea level) | 2.600 | 100 | 1600–2000 | 1600–4000 |
| Construction technique | Concrete | Prefabricated block | Puzzolanic brick | Molded concreted |
| Biogas production | $3m^3$ / day | 150 $m^3$* | 2–4 hr/day | 2–$3m^3$ / day |
| Initial raw material | manure | Composted Chicken–manure | Pre–composted manure and straw | Pre–composted manure and straw |
| Periodic raw material | manure | Chicken manure water | Fresh human feces Compost and water | Fresh sheep manure |
| Biogas uses | cooking | cooking | Cooking and illumi- nation | Cooking and illumi- nation |
| Effluent uses | agriculture | agriculture | agriculture | agriculture |
| Slude uses | agriculture | agriculture | agriculture | agriculture |
| Sanitation date | | | 10–4 coliforms/ml 500 viable eggs | 95 o/o death rate among parasites |

* Estimated or expected data
** OLADE built one digester similar to those described, which total 10.

# 3. DIGESTER: XOCHICALLI–MEXICO TYPE

## 3.1 BASIC DESIGN

### Generalities

The digester is an uderground rectangular, horizontal pit with a separate gasometer. It is loaded through one end and the liquid effluent and digester sludge are discharged through the opposite end. There are 4 outlets at this end: biogas, solid and foamy scum, liquid bio—fertilizer, and semi—liquid bio—fertilizer in the form of sludge.

The construction of the gasometer is similar to that described for the OLADE—Guatemala type biogas plant, with a gasholder made from 26 gauge galvanized metal, protected by anti—rust paint and interconnective polyethylene piping; although a gasometer larger than one described in subsequent pages is preferable, in order to avoid the entry of excess pressure due to gas accumulation.

### Operation

Continuous or semi—continuous loading. Discharge at short or long intervals, as convenient.

### Location

Near the source of the raw material, preferably below the stable or beds of the contributing animals. The topography of the terrain may vary becuase of the nature of the project.

## 3.2 CONSTRUCTION MATERIALS

Any type of material can be used, but low—cost ferrocement is recommended. The versatility of the system means that the digester can be built by the users themselves.

We use as examples a digester with a 16 $m^3$ capacity another with a 12 $m^3$ capacity, which respectively, can process the manure from five and eight dairy cows kept in a barn. The former produces between 8 and 12 $m^3$ of biogas per day, and the latter, between 4 and 8 $m^3$.

This type of digester can be built on a small family scale or on a large scale for industrial use.

In any case, the use of local construction materials, such as compacted earth, brick, stone or ferrocement, is recommended, in order to keep down costs.

## LIST OF MATERIALS FOR THE OLADE–XOCHICALLY–MEXICO TYPE DIGESTER OF 16 $m^3$

| MATERIALS | QUANTITY | |
|---|---|---|
| 1. Cement | 30 | bags of 45 kg. |
| 2. River sand | 3.5 | $m^3$ |
| 3. Gravel (approximately 1" diameter) | 1.0 | $m^3$ |
| 4. Tie wire | 15 | kg. |
| 5. Chicken wire | 3 | rolls (120 $m^2$) |
| 6. Cement pipes 10" x 3' | 2 | units |
| 7. PVC pipes 1/2" x 5 m. | 3 | units |
| 8. Elbows 1/2" | 10 | units |
| 9. Universal unions 1/2" | 2 | units |
| 10. Couplers 1/2" | 3 | units |
| 11. Stopcock 1/2" | 4 | units |
| 12. Tees of 1/2" | 3 | units |
| 13. Nipples of 1/2" x 3" | 8 | units |
| 14. Nipples of 4" x 10" | 1 | unit |
| 15. Nipples of 2" x 10" | 1 | unit |
| 16. Stopcock 2" | 1 | unit |
| 17. Stopcock 4" | 1 | unit |
| 18. Wire mesh of 1/4" x 12 m. | 35 | units |
| 19. Water proofing agent | 15 | kg. |
| 20. Wood boards of 3/4" x 6" x 6' | 14 | pieces |
| 21. Rectangle shaped scum gate of the metal plate of 1/8" mounted on an iron angle frame of 1–1/2 x 1–1/2 x 1/8" with screws and knobs incorporated. Of 0.30 x 0.60 m. (with rubber gasket) | 1 | piece |

### GASOMETER SINK

| | | |
|---|---|---|
| 22. Cement | 11 | bags of 45 kg. |
| 23. River sand | 1.5 | $m^3$ |
| 23. Gravel | 0.5 | $m^3$ |
| 25. Wire mesh of 1/4" x 12 m. | 5 | units |
| 26. Tie wire | 2 | kg. |
| 27. Bricks 2" x 4" x 8" | 450 | units |
| 28. Gasholder (according to the design) | 1 | unit |

## LIST OF MATERIALS FOR THE OLADE–XOCHICALLY–MEXICO TYPE DIGESTER OF 12 $m^3$

| MATERIALS | QUANTITY | |
|---|---|---|
| 1. Cement | 23 | bags 45 kg. |
| 2. River sand | 2.5 | $m^3$ |
| 3. Gravel | 1.0 | $m^3$ |
| 4. Tie wire | 15 | kg. |
| 5. Chicken wire (3/4") | 86 | $m^2$ |
| 6. Cement pipes 10" x 3' | 2 | units |
| 7. Laminated polyethylene | 20 | $m^2$ |
| 8. Wire mesh of 1/4" x 12 m. | 25 | units |
| 9. PVC pipes 1/2" x 5m. | 3 | units |
| 10. Elbows 1/2" | 10 | units |
| 11. Universal union 1/2" | 2 | units |
| 12. Couplers 1/2" | 3 | units |
| 13. Stopcock 1/2" | 4 | units |
| 14. Tees of 1/2" | 3 | units |
| 15. Nipples of 1/2" x 3" | 8 | units |
| 16. Nipples of 4" x 10" | 1 | unit |
| 17. Nipples of 2" x 10" | 1 | unit |
| 18. Stopcock 4" | 1 | unit |
| 19. Stopcock 2" | 1 | unit |
| 20. Wood boards of 3/4" x 6" x 6' | 4 | units |
| 21. Waterproofing agent | 15 | kg. |
| 22. Rectangle shaped scum gate of the metal plate of 1/8" mounted on an iron angle frame of 1–1/2 x 1–1/2 x 1/8" with incorporated knobs and screws. Of 0.30 x 0.60 m. (with rubber gasket) | 1 | piece |
| 23. Double gasometer with galvanized plate or fyberglas polyester resin of 1.5 $m^3$ capacity | 1 | piece |

### 3.3 CONSTRUCTION TECHNIQUES

There is an infinite number of variations, adaptable to conditions of site, sub–soil, topography, climate, use, materials, labor, etc.

We will cite a typical case and point out the options:

Phases:

a. Site Selection;
b. Calculation, choice of size of plant (s), and outline;
c. Technique to be used;
d. I Excavation and assembly
   II Cutting and assembling tank (if it is of ferrocement but no larger than 20 $m^3$) and excavation of the same;
e. Casting, etc., of base and walls;

f. Preparation of floor—covering
g. Completion and istallation of loading and unloading devices;
h. Accessories.

### A. Site Selection

There are different factors that affect choice of site. They are listed as follows:

—Where there is a stable or farm
—Where there will be a stable or farm
—Where biodegradable products are available (human, garbage, agroindustry, water lilies, pasture, fushery, etc.)
—Where there is a good slope (topography)
—Adequate terrain (soil consistency, subterranean water level)
—Others

B. Calculation, Choice of Size (s), and Outline. Once the quantity and quality of organic materials to be processed are known, the volume of the digester is calculated.

This is when it will be decided if one or more tanks will be built, according to be availability of land, etc. For example, if the tank that would provide the required volume were too large, given the land available, (for example having chosen a site with a length width ratio of 6 to 1), two shorter tanks would be built although they would be wider and cost a little more; this would, at the same time, simplify maintenance. In other words, there are both pros and cons.

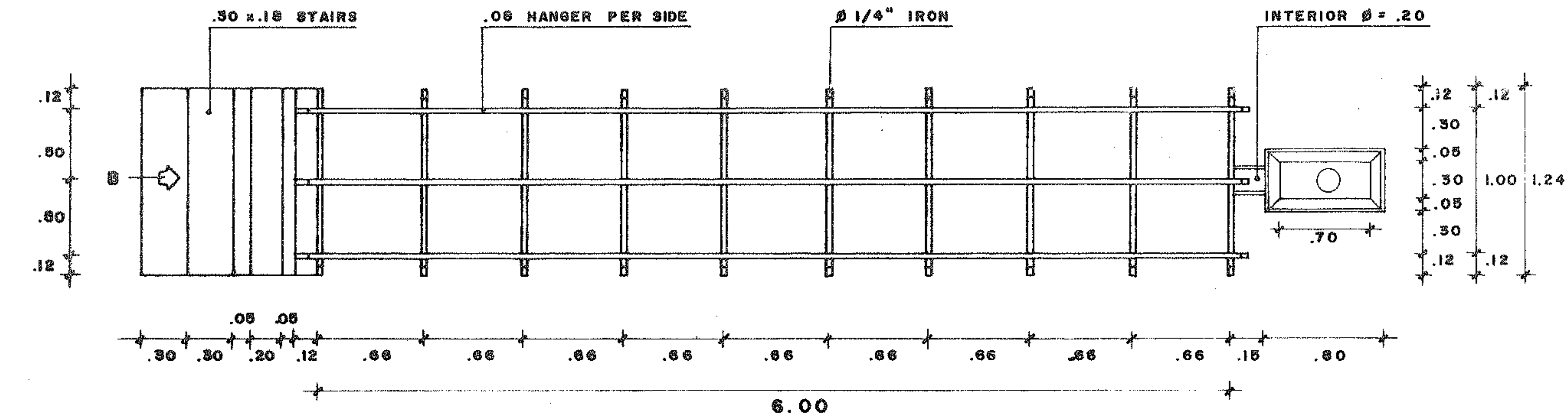
Having decided on the size and number of digesters proceed to the outline. The ideal is to locate the digesters in such a way that the outlet pipe is lower, so as to take advantage of gravitational force unloading, without the need for making a ramp. Otherwise, another excavation can be made, permitting entry as far as the valves with buckets, drums, pipes, etc. In the last instance, a pump can be constructed to transfer effluentes and later remove them. The pump can be manual or mechanical (aeolic, electric or motorized.)

The outline is done with stakes, cord, or lime. By marking each part in the selected place, logically working out the operation, and correcting possible problems, a final outline is made.

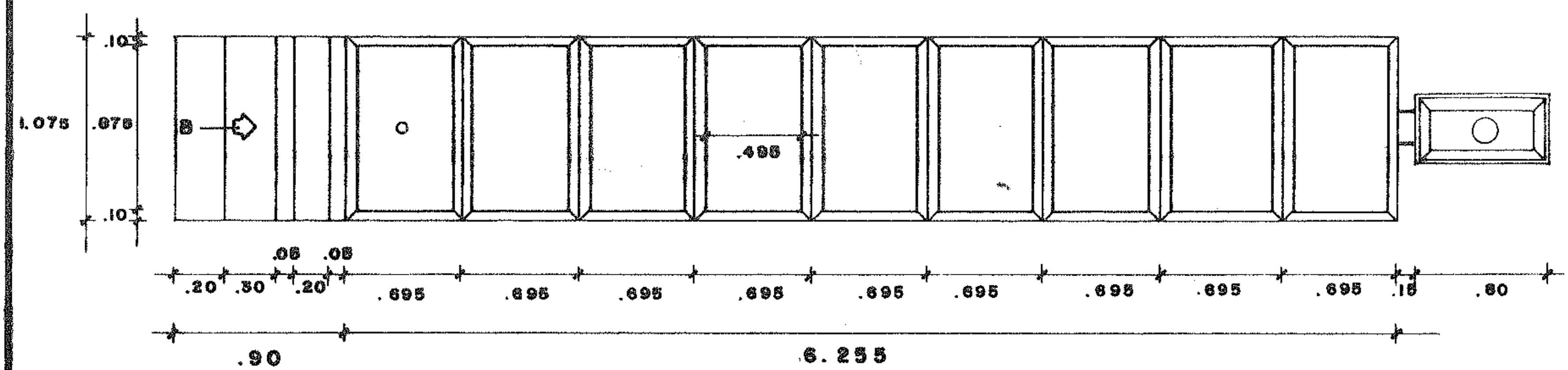
An intelligible drawing should be made of the final arrangement. This is when the construction sequence will be decided (depending on various factors, as will be seen in point C)

### C. Technique to be Used

The technique to be used depends on an infinite number of external and local factors, but it is recommended that the ferrocement technique be followed (see attached descriptions for general use); although even within it, variants can be chosen according to particular requirements. Thus, it would be best to accommodate the animals above the digester, thereby doing away with the need for a floor for them, faciliting the loading process, and definitely improving the operation from a thermal point of view, since it will be used as the bed for the animals whose body temperature is 36° centigrade.




IRON REINFORCEMENT OF BASE (PLANT) SCALE. 1:40



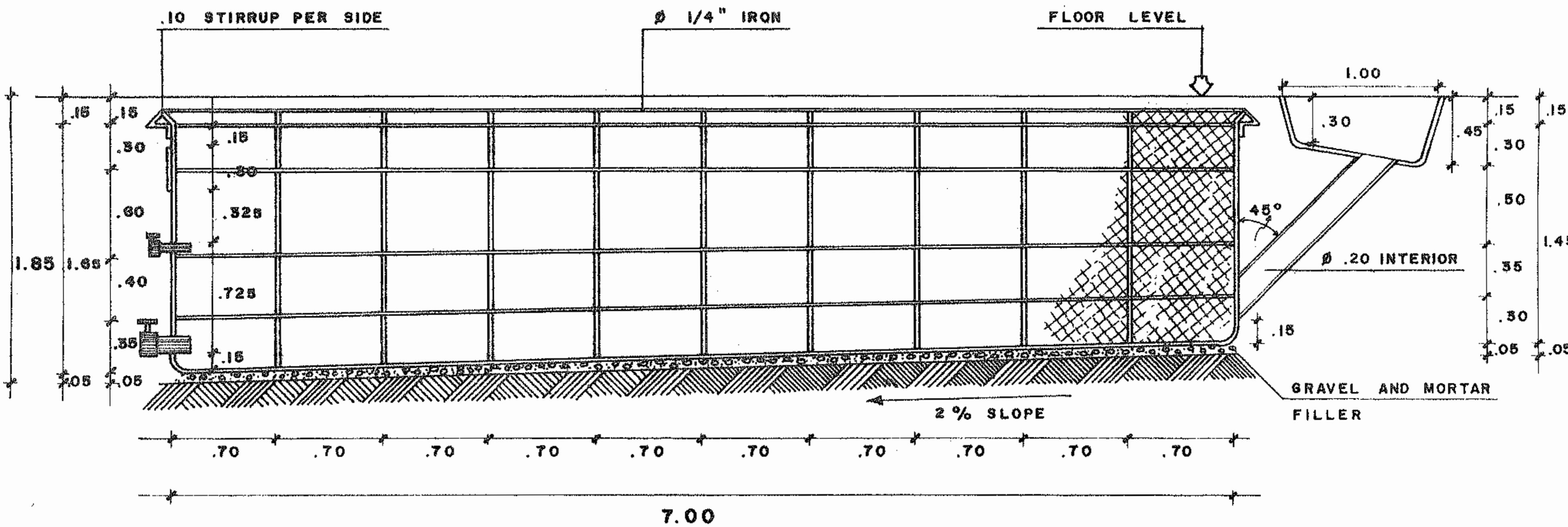

COVERS (PLANT) SCALE. 1:40

olade

project: FERROCEMENT CONSTRUCTION DETAIL

| | | |
|---|---|---|
| PLATE 1 | contains: PLANTS | scale: INDICATED |
| | capacity: (inside) 6 M3 | type: XOCHICALLI-MEXICO |

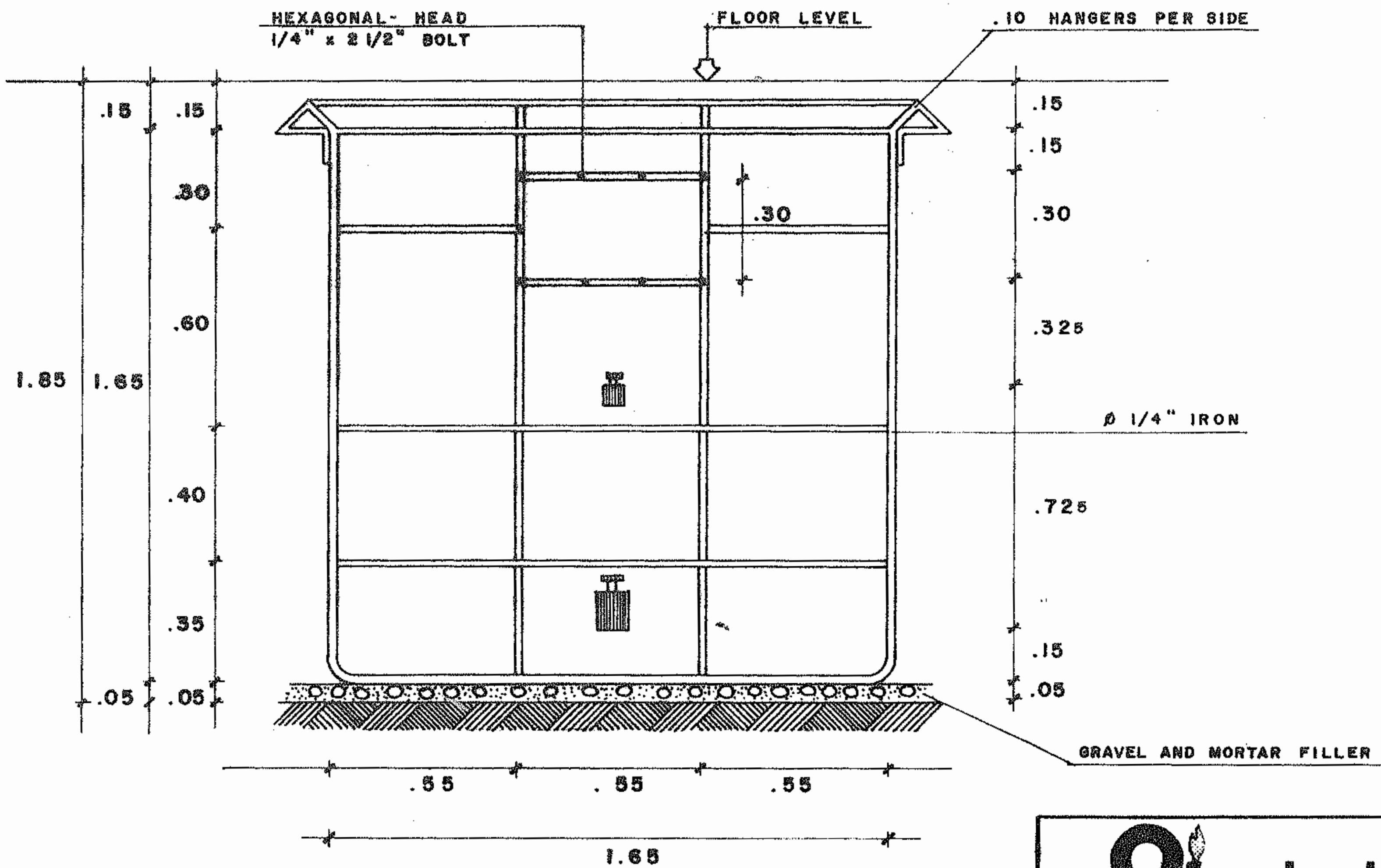
# IRON REINFORCEMENT ( LATERAL ELEVATION ) SCALE. 1:40




olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: LATERAL ELE. | scale: INDICATED |
| 2 | capacity: 16 M3 | type: XOCHICALLI - MEXICO |

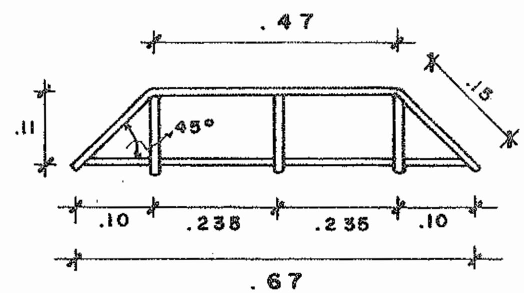
# IRON REINFORCEMENT (FRONT ELEVATION) SCALE. 1:20



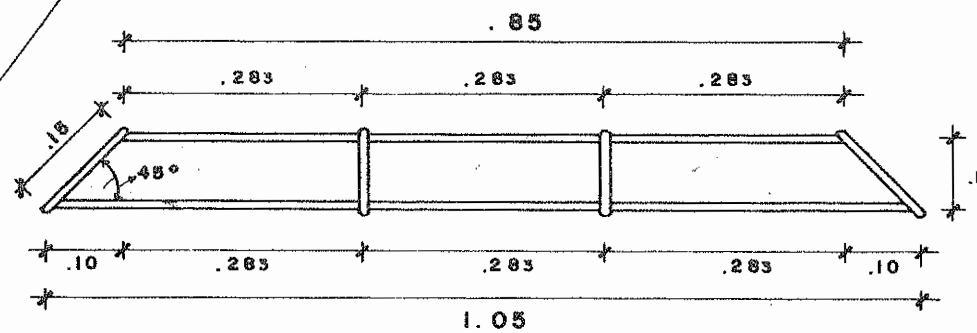

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: ELEVATION | scale: INDICATED |
| 3 | capacity: 16 M3 | type: XOCHICALLI-MEXICO |

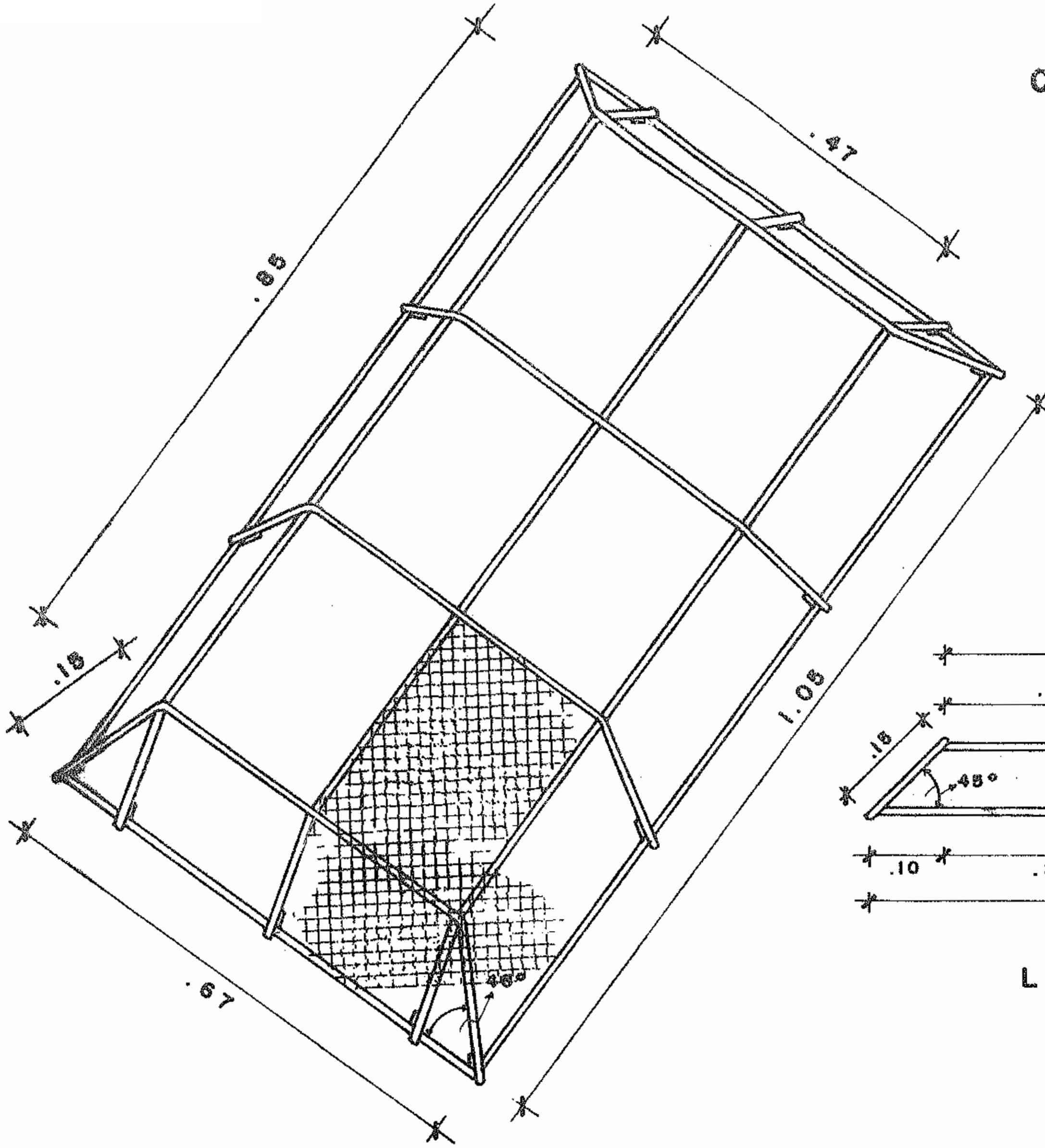
## COVERS (IRON REINFORCEMENT)




FRONT ELEVATION ESC. 1: 15




LATERAL ELEVATION UNSCALED

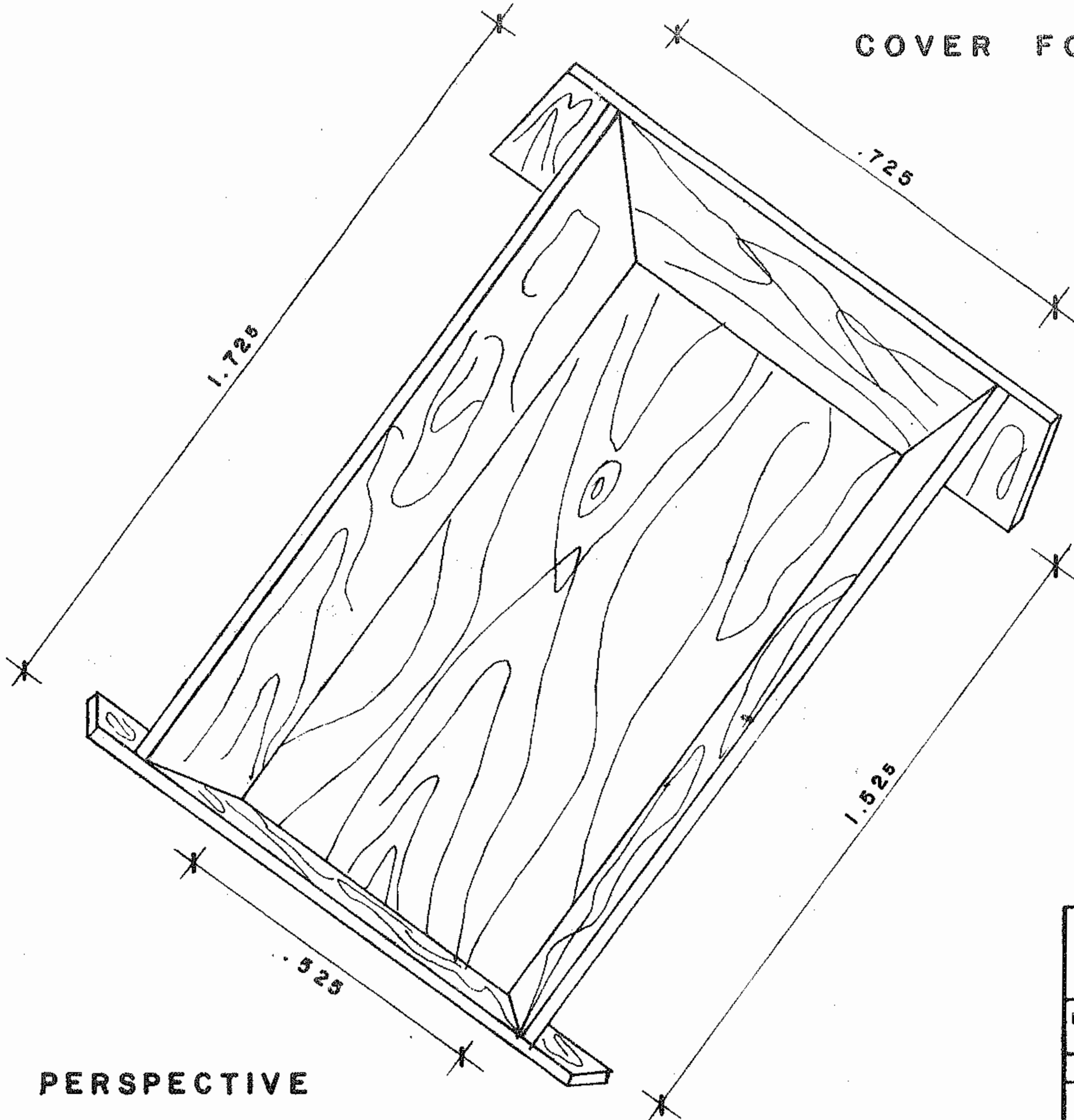



PERSPECTIVE

olade

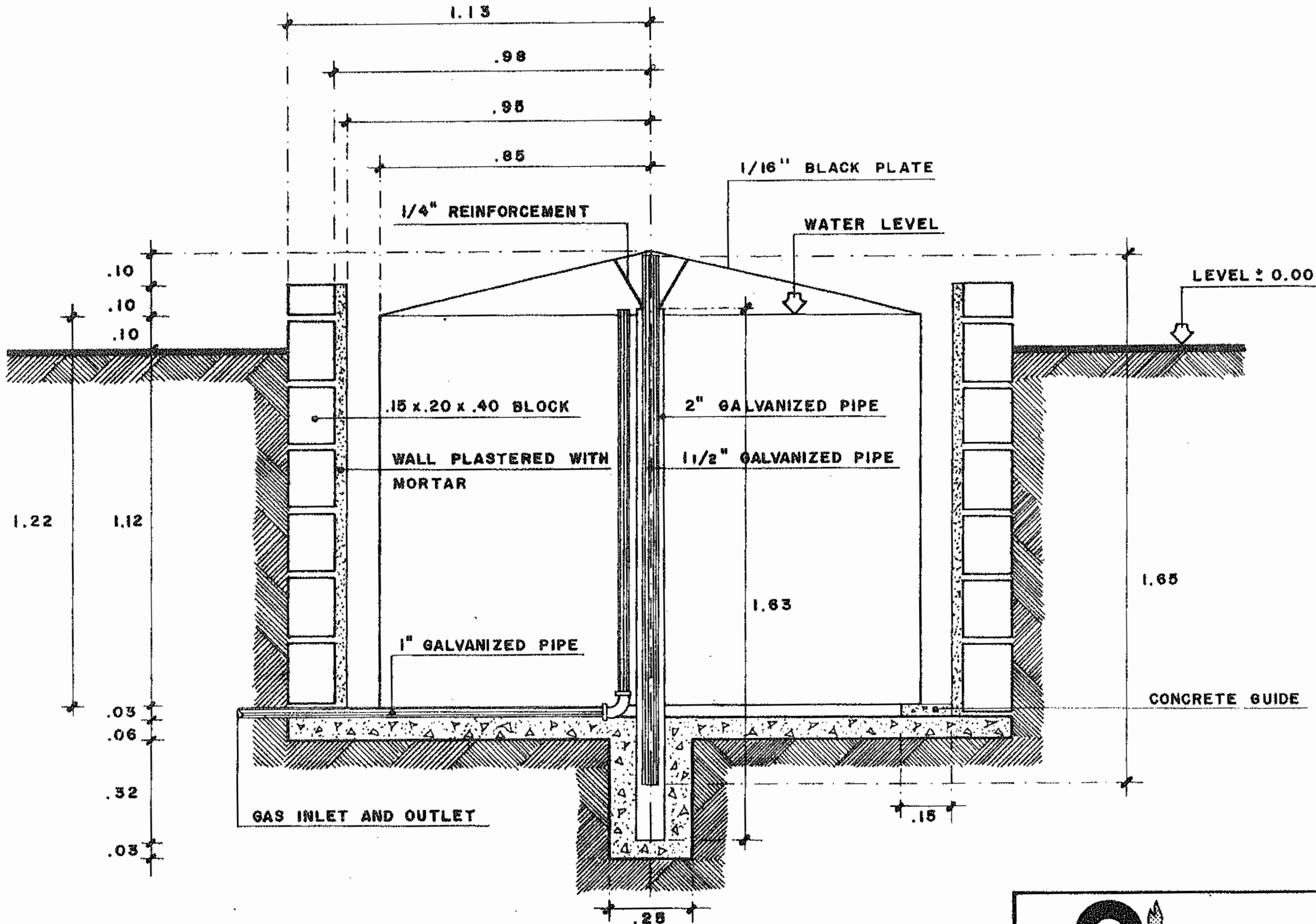
| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: ELEVATION PERSPECTIVE | scale: |
| 4 | capacity: (inside) 6 M3 | type: XOCHICALLI-MEXICO |

## COVER FORM



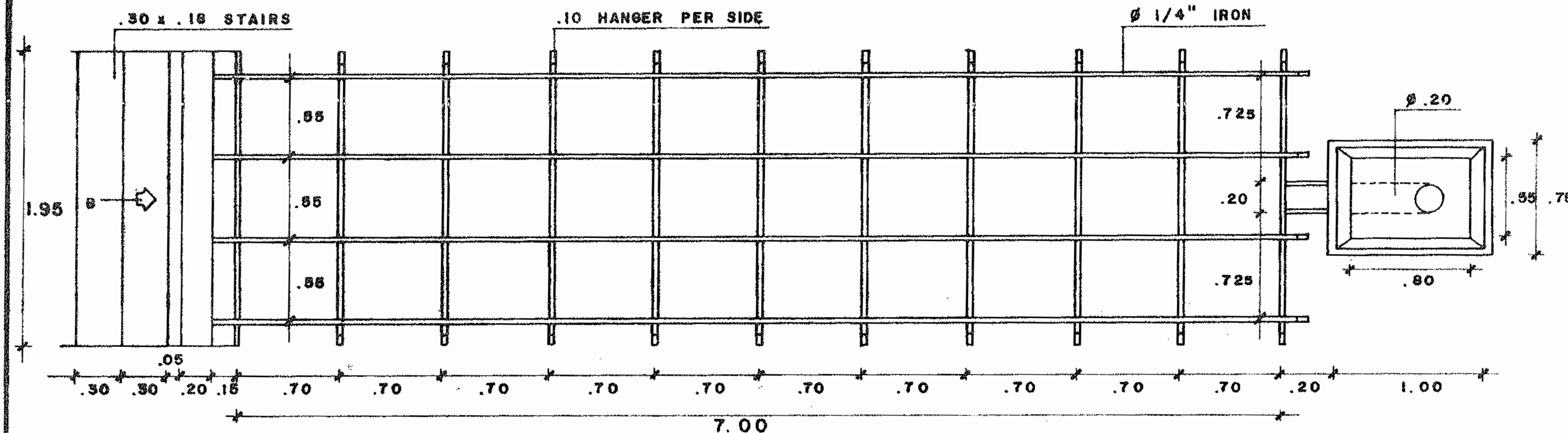

PERSPECTIVE

| | | |
|---|---|---|
| olade | | |
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: PERSPECTIVE | scale: |
| 5 | capacity: 16 M3 | type: XOCHICALLI-MEXICO |

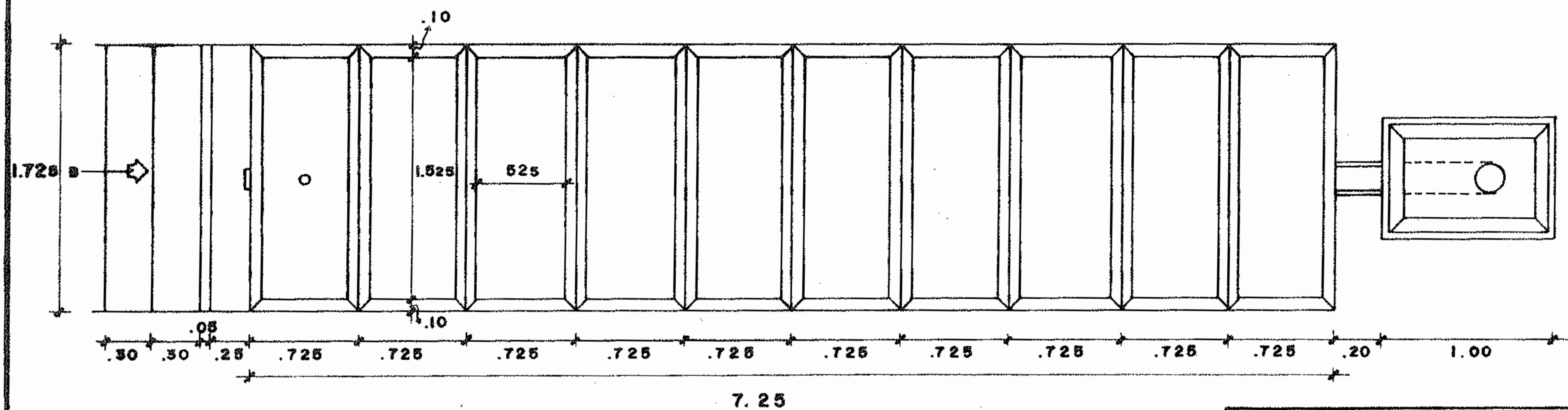



SECTION B - B' SCALE 1:20

| olade | |
|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | |
| PLATE 6 | contains: SECTION · scale: INDICATED |
| | capacity: 3 m³ GASOMETER · type: XOCHICALLI-MEXICO |




IRON REINFORCEMENT OF BASE (PLANT) SCALE. 1: 40

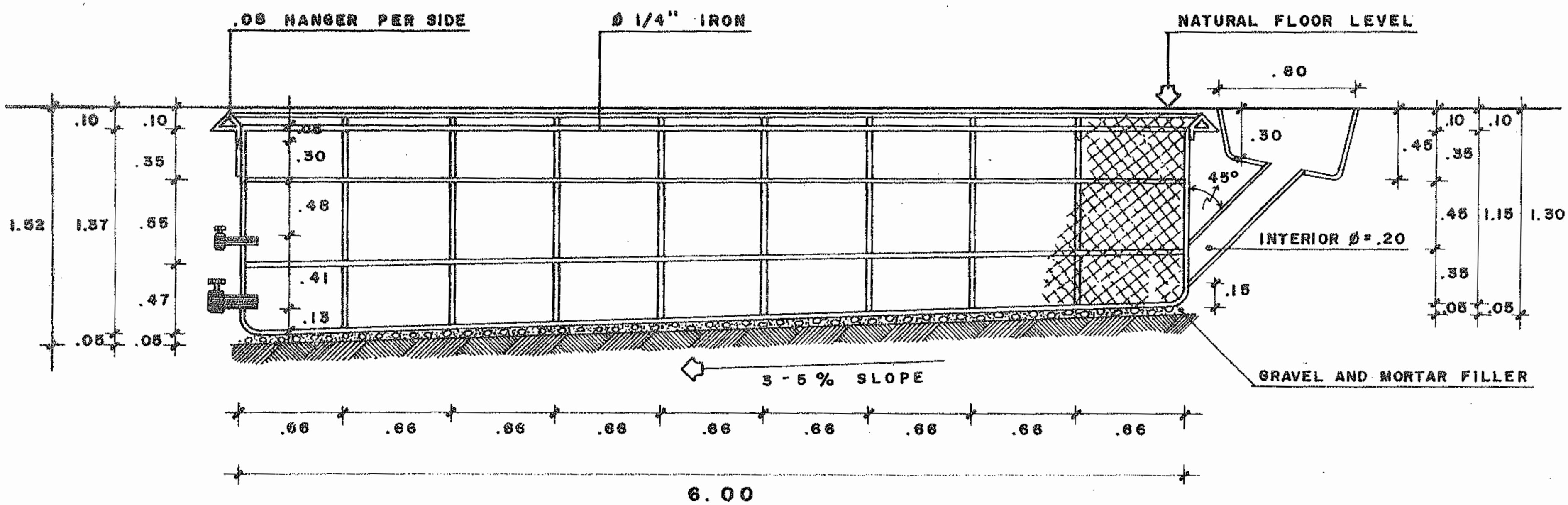



COVERS (PLANT) SCALE. 1:40

olade

project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: PLANTS | scale: INDICATED |
|---|---|---|
| 1 | capacity: 16 M3 | type: XOCHICALLI-MEXICO |

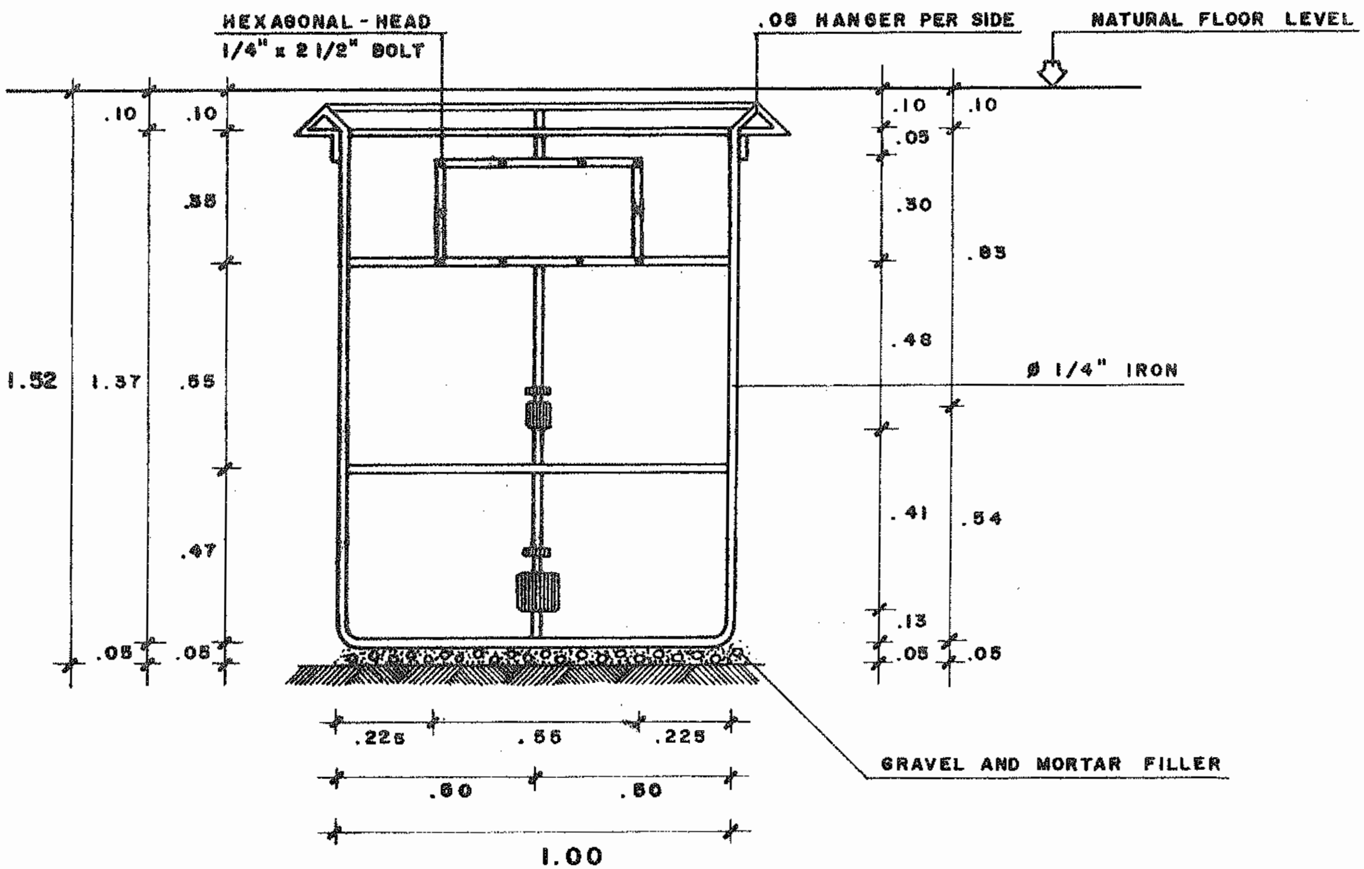



IRON REINFORCEMENT (LATERAL ELEVATION) SCALE. 1:40

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: L. ELEVATION | scale: INDICATED |
| 2 | capacity: (inside) 6 M3 | type: XOCHICALLI-MEXICO |

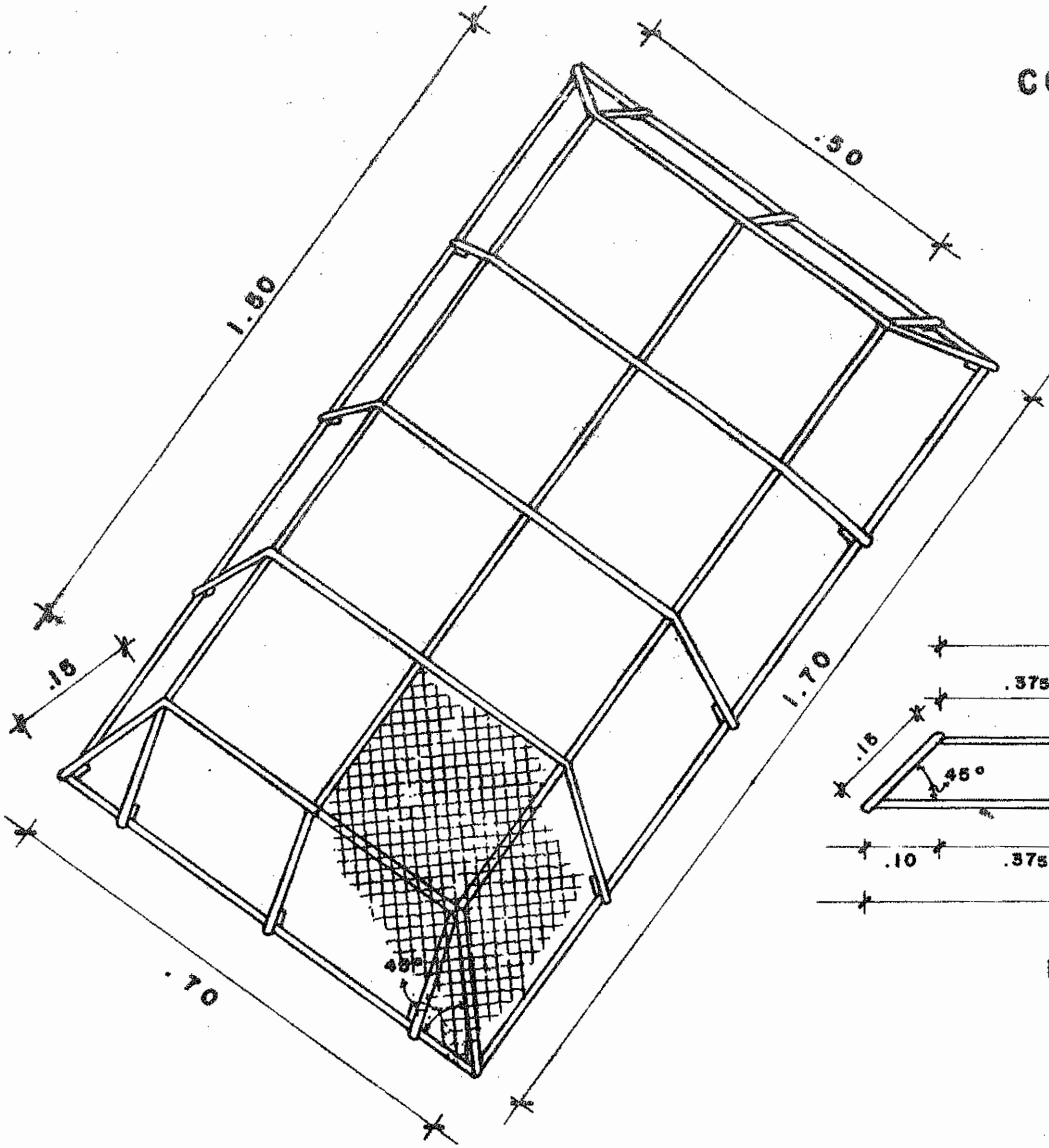
# IRON REINFORCEMENT (FRONT ELEVATION) SCALE. 1:20



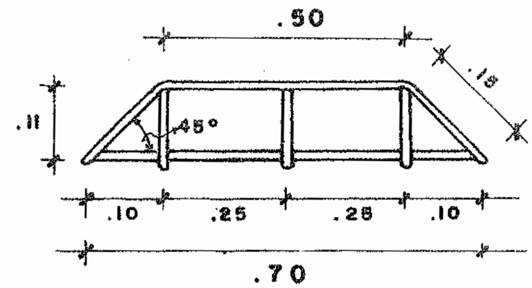

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 3 | contains: F. ELEVATION | scale: INDICATED |
| | capacity: (inside) 6 M3 | type: XOCHICALLI- MEXICO |

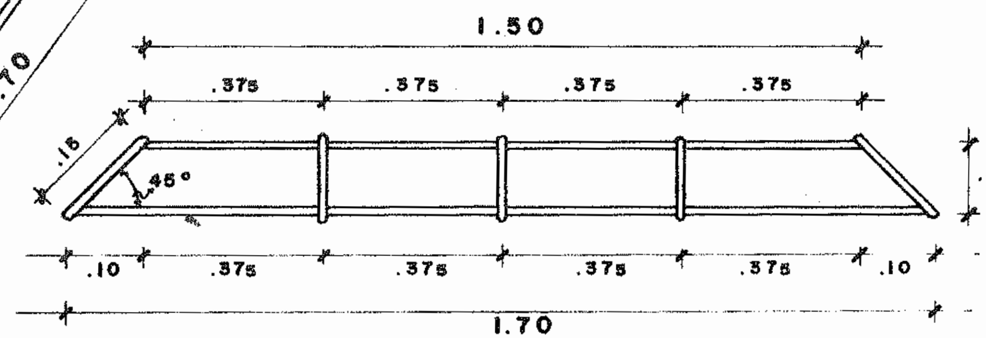
# COVERS (IRON REINFORCEMENT)




PERSPECTIVE




FRONT ELEVATION SCALE. 1 : 15

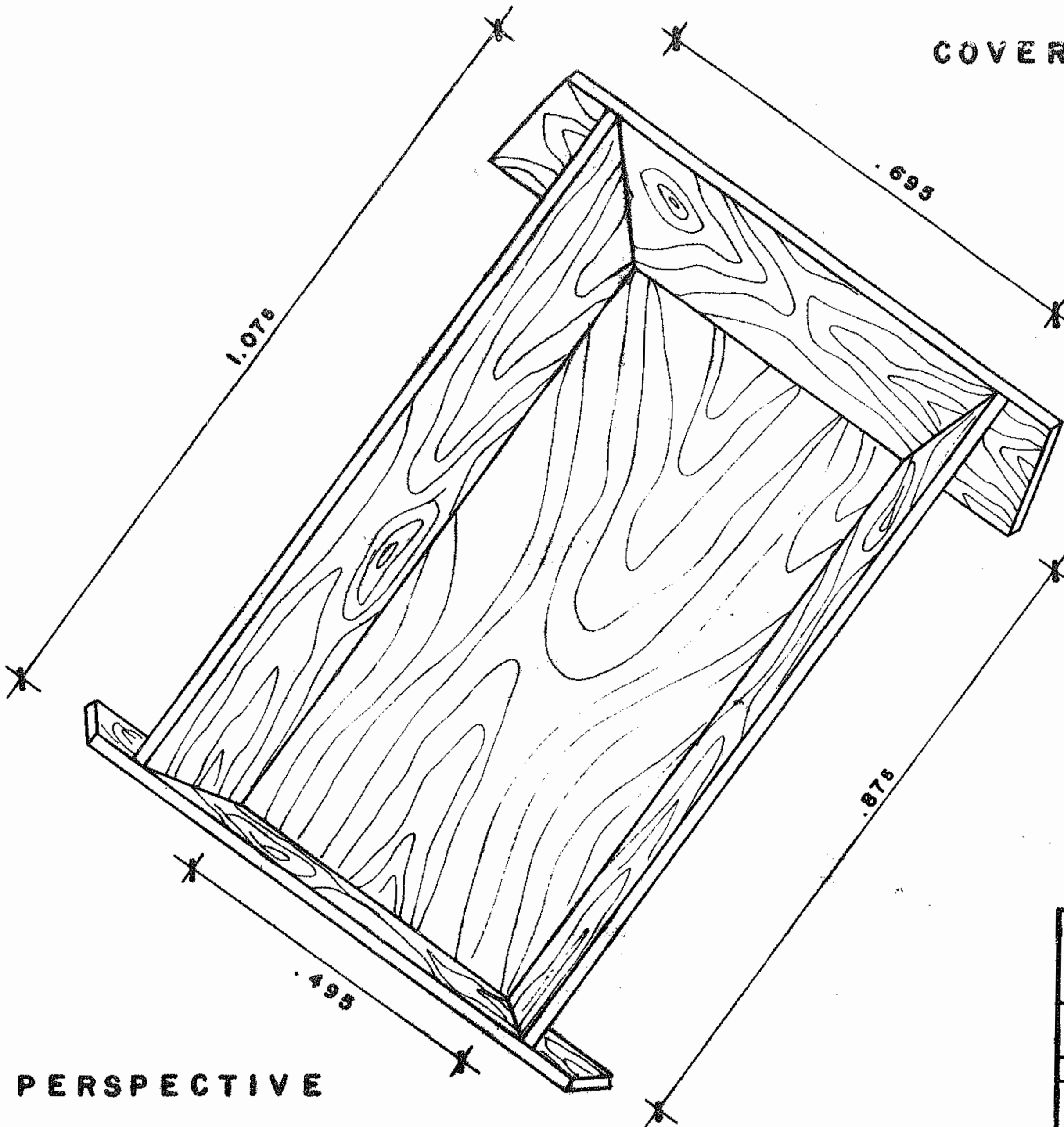



LATERAL ELEVATION SCALE. 1 : 15

olade

| | | |
| --- | --- | --- |
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 4 | contains: ELEVATION PERSPECTIVE | scale: INDICATED |
| | capacity: 16 M3 | type: XOCHICALLI-MEXICO |

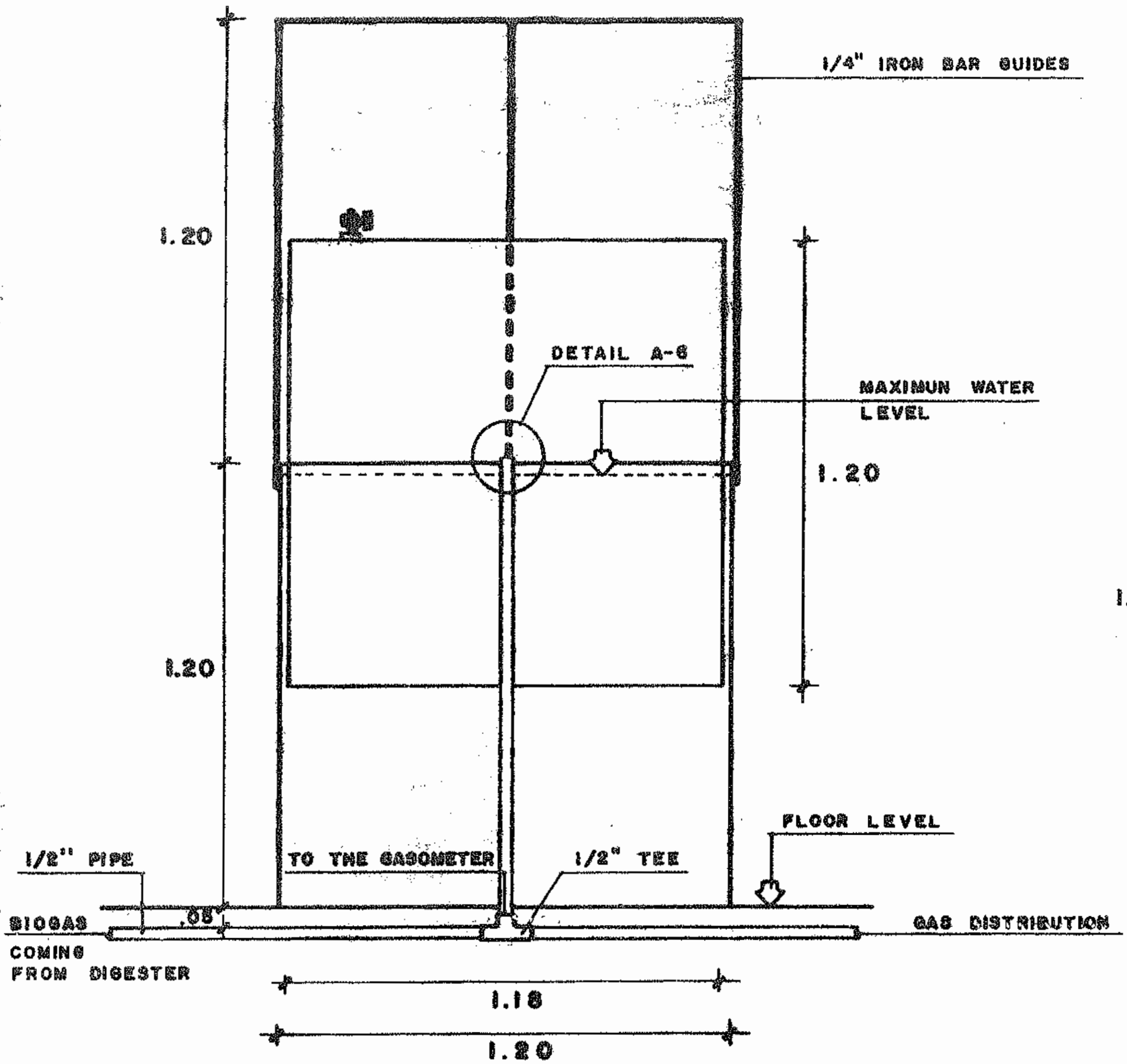
## COVER FORM



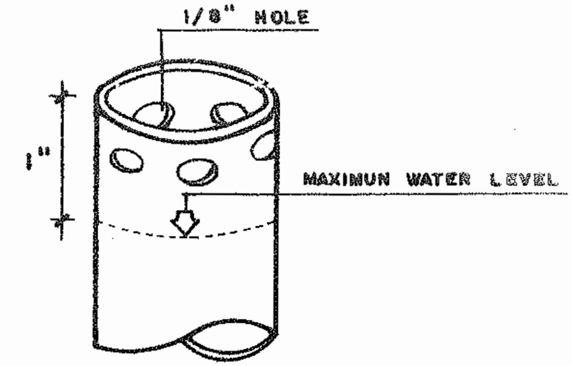

PERSPECTIVE

olade

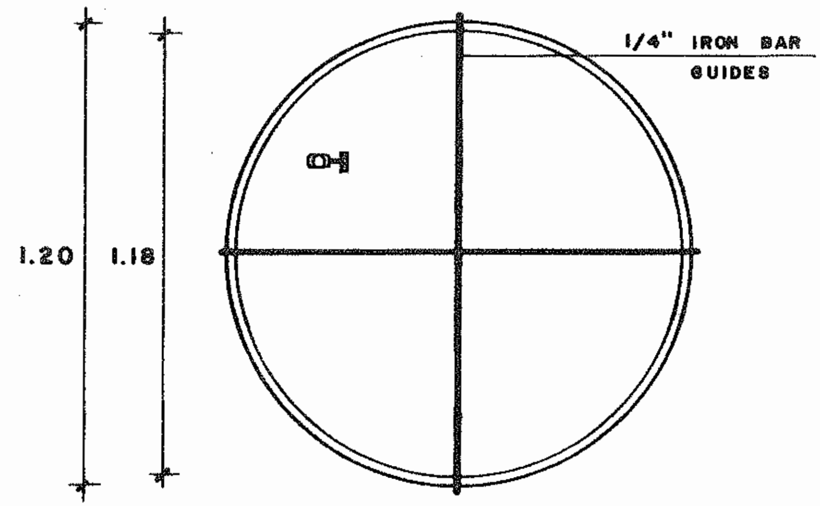
| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE | contains: PERSPECTIVE | scale: |
| 5 | capacity: (inside) 6 M3 | type: XOCHICALLI-MEXICO |




ELEVATION SCALE. 1:20




DETAIL A-6
FEEDER PIPE




PLANT SCALE. 1:20

olade

project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: PLANT-DETAIL ELEVATION | scale: INDICATED |
|---|---|---|
| 6 | capacity: (inside) 6 M3 | type: XOCHICALLI-MEXICO |

### 3.4 RAW MATERIAL FOR DIGESTER

For this type of digesters, organic waste, sewage, manure, organic industrial wastes, crop residues, etc., may be used as raw material. To the mixture of solids introduced into the digester liquid (water and/or innoculators) must be added until there is an approximately 90 o/o dilution.

### 3.5 OPERATION OF THE DIGESTER

It is similar to that described for the Chinese system; in other words, its load is semi—continuous or continuous; the initial load is preferably made with pre—composted material. The addition of the initial liquid is preferably a mixture, with 10 o/o of the residual liquid from another digester or from a septic tank.

The digester should be loaded until the liquid covers the mouth of the inlet pipe. The skimming process takes place 2 or 3 times a year, keeping in mind that the first scum forms, 15 days after the initial loading, so that it becomes necessary to drain liquid as far as the lower level of the scum removal outlet and to extract the scum with a device designed for the at purpose, by dragging.

It is necessary to ensure that there is no leakage, particularly through the screws of the scum removal outlet.

#### Unloading the Digester

This ought to be done in such a way that the level does not fall below 50 cm. from the bottom, so as not to stop the process. The unloading can be done daily, enery two weeks, montly, etc. Two—thirds of the daily load can be unloaded as liquid, and a quarter as sludge.

The water that is collected can be recirculated to economize it.

### 3.6 UTILIZATION OF DIGESTER PRODUCTS

The sludge from the digester has a moisture content of 88 o/o, so it can be handled like slurry. It has the advantage of being a finished and concentrated product; applied to crops, it yields more as a function of cumulative effects.

The two products mentioned can be applied to the soil as fertilizer, as inert material, or they can be used in hydroponic cultivation. The drainage liquid can also serve as food for fish and birds. Its use with larger animals (10 o/o protein, dry base, in addition to vitamins, minerals, homones, etc.), is currently being studied. The scum can be recycled or composted.

### 3.7 COMMENTS ABOUT THE APPLICATION OF THIS TECHNOLOGY

From experience acquired over the first constructions of the XOCHICALLI—MEXICO type digesters, some defficiencies have been noted caussed by lack of adequeate experience in construction with ferrocement, this repercutes in the hermetical characteristic of the digester. Another problem noticed is that related to the system of initial loading.

Therefore, the main problems observed are:

1. Inefficient sealing in the union of the taps and the cealing, this causses gas leaks.

2. Gas leaks in the flood gate due to utilization of gaskets and sealers which are not hermetical.

3. During the initial load, the vegetal fybers and the digested materials and manure tend to float rapidly, impeding the expected bio—degradation.

In order for this technology to comply with its objectives, changes in the design are being made with the purpose of avoding the mentioned problems. Nevertheless, it is very important to bear in mind the type of sand and quality of cement to be used, since if those are not the best, this will also create big problems.

The main changes in the design recommended are:

1. To construct the cealing in a semicylindrical form and forming a sole body together with the walls (see appended chart)

2. To make the flood gate in accordance to the one of the design in the appended drawing (appended chart).

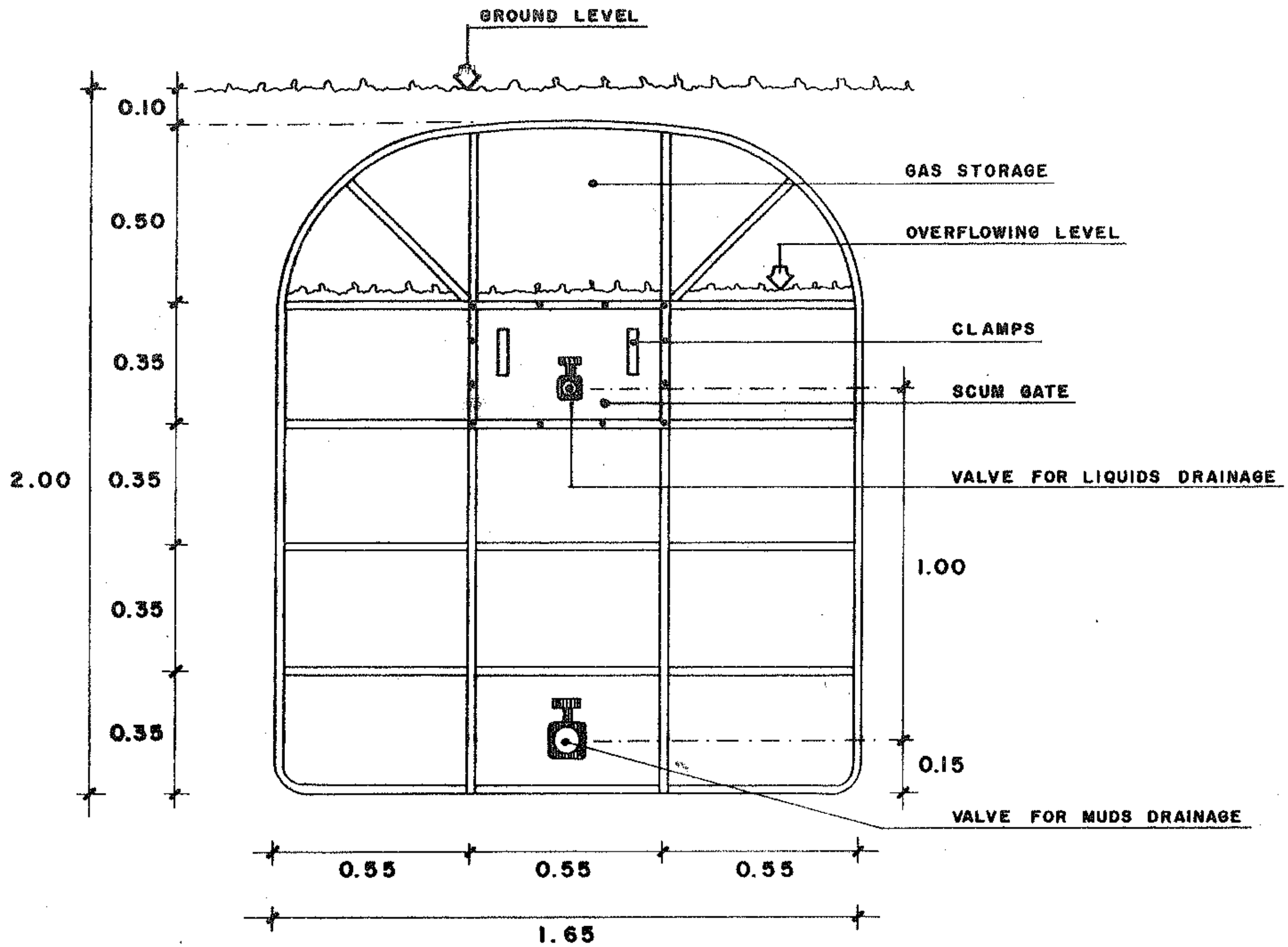
3. The initial load of the digester should preferently be made as follows:

a) Exclusively with manure and water, not using vegetal fybers. The latter could be miced with the manure when the digester has regularized its fermenting cycle and gas production, adding such in the way established in point 3.5 dillution could be made with the required volume of water and utilizing no more than 30 o/o of the liquid efluent, as recycling inoculous material.

b) With 50 o/o digested muds (approximately 15 to 20 days of previous digestion in another digester) to avoid un—expected floatation of cellulose vegetal material.

4. Construction of the gasometer could be avoided by constructing the plant with a semicylincrical cealing as indicated in the diagram.

5. The semicylindrical cealing shall stay underground once construction is finished, to secure a better preservation of internal heat inside the digestor.

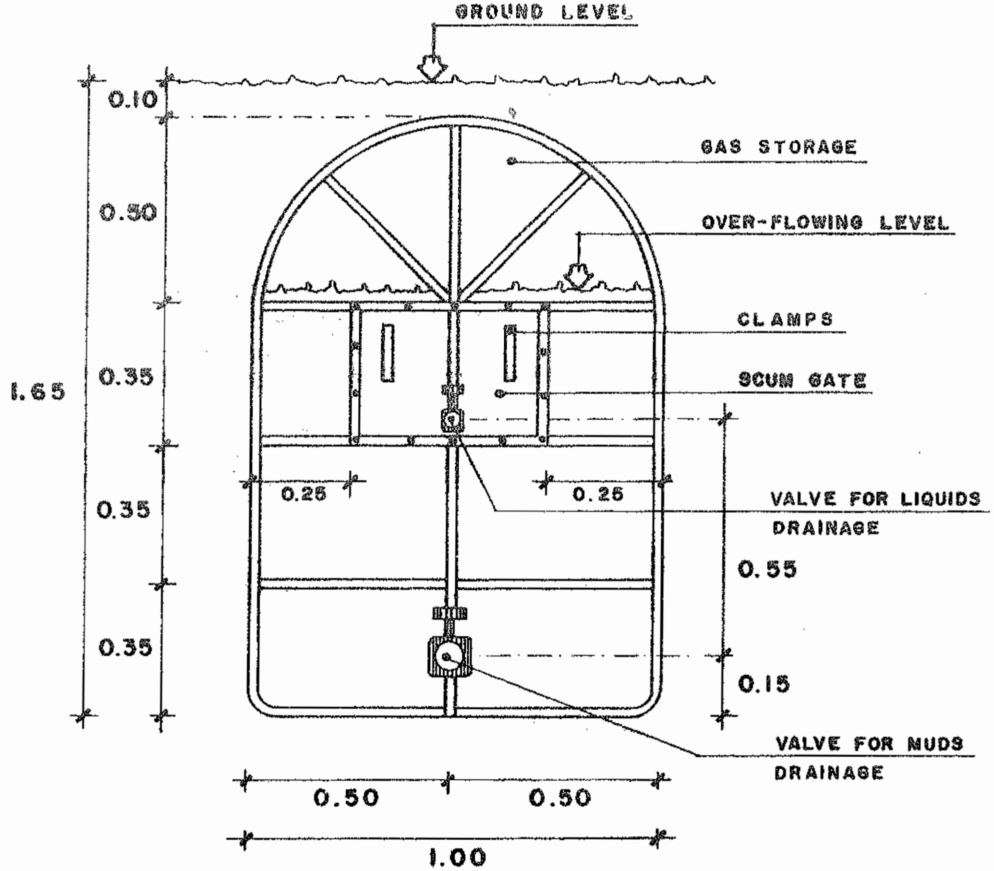



FRONT ELEVATION

SCALE . 1 : 20

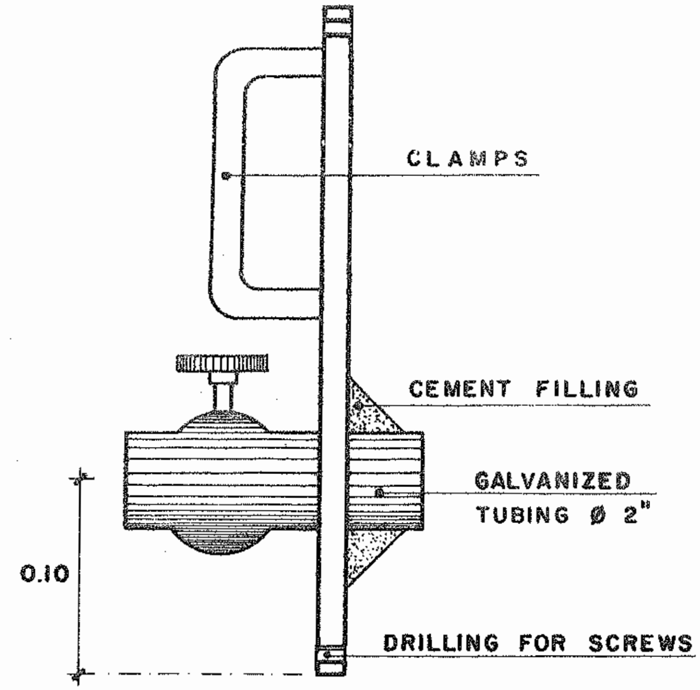
olade

| project: DETAIL OF MODIFICATIONS FOR CEALING AND FLOOD GATE | | |
|---|---|---|
| ANNEX | contains: ELEVATION F. | scale: INDICATED |
| 1 | capacity: 16 M³ | type: XOCHICALLI-MEXICO |




## FRONT ELEVATION

SCALE. 1:20




## SIDE VIEW

## FLOOD GATE AND VALVE FOR LIQUIDS DRAINAGE

SCALE. 1:4

olade

| | | |
|---|---|---|
| project: DETAIL OF MODIFICATIONS IN SEALING AND FLOOD GATE | | |
| ANNEX 2 | contains: ELEVATION F. | scale: INDICATED |
| | capacity: 6 $M^3$ | type: XOCHICALLI-MEXICO |

## 4. DIGESTER: IIE–MEXICO TYPE (IIE – ELECTRICAR RESEARCH INSTITUTE – INSTITUTO INVESTIGACIONES ELECTRICAS

### 4.1 BASIC DESIGN

This type of digester is of a horizontal spreaded construction. The body is located undergound with the purpose of giving a good thermal isolation. It has a primary gas storage inside the digester (incorporated gasometer). Its geometry and operation form have been designed to secure a continuous functioning.

The entry for the mixture is located in the lower part of the digester and unloading operation culd be done by the unloading pipe or overflowing device towards the unloading sink.

It is a family digester of 10 $m^3$, which is located nearby the stable on source of raw material, as well as nearby the site where the gas and the fertilizer will be utilized.

### 4.2 CONSTRUCTION MATERIALS

Construction of the digester can be done by using different materials, which should be selected according to the economic capabilities for initial investment and to work within the established guidelines. If possible, the construction materials that can be found in the site where the digester is located should be used, and we recommend to use the conventional techniques of concrete or ferrocement to obtain better construction facilities.

The following is a type example for construction of a 10 $m^3$ digester.

**LIST OF MATERIALS FOR CONSTRUCTION OF A DIGESTER IIE–MEXICO TYPE OF 10 $m^3$**

| MATERIALS | QUANTITY | |
|---|---|---|
| 1. Cement | 40 | bags of 45 kg. |
| 2. River sand | 4.0 | $m^3$ |
| 3. Gravel | 1.0 | $m^3$ |
| 4. Iron 1/4" x 12 m. | 35 | pieces |
| 5. Tie wire | 15 | kg. |
| 6. Chicken wire | 3 | rolls (120 $m^2$) |
| 7. Waterproofing agent | 20 | Kg. |
| 8. Cement pipes of 10" x 1 m. | 6 | units |
| 9. Wood for ramp and structure | | enough |
| 10. Galvanized tubing 1" x 5 m. | 2 | units |
| 11. Elbows 1" | 4 | units |
| 12. Tee 1" | 1 | unit |
| 13. Stopcock 1" | 1 | unit |
| 14. Nipples of 1" x 3" | 3 | units |
| 15. Couplers of 1" | 1 | unit |
| 16. Universal union 1" | 1 | unit |

| | | |
|---|---|---|
| 17. Reduction couplers of 1/2" x 1" | 1 | unit |
| 18. Galvanized tubing of 1/2" x 5 m. | 2 | units |
| 19. Stopcock 1/2" | 1 | unit |
| 20. Coupler of 1/2" | 1 | unit |
| 21. Nipple of 1/2" x 3 | 2 | units |
| 22. Circular metal plate of 60 cm. x 1/8" thickness (access and cleaning gate) | 1 | unit |

### 4.3 CONSTRUCTION TECHNIQUES

The construction technique utilized in this digester varies according to the type of selected materials.

When constructing the digester with ferrocement technique, it must be checked that the mixture has the sufficient water (a little dry mixture), so that it will be fixed in the porosities left by two coats of chicken wire that is placed; then, the walls are polished with mixture, polishing them especially with waterproofing element in the internal part of the digester, with the purpose of impeding humidity and gas leaks.

The unions of the feeding and unloading pipes must stay completely sealed with mixture.

The construction plans of the digester with ferrocement techniques are as follows.

### 4.4 RAW MATERIAL FOR DIGESTERS

This digester utilized a technology of high dillution, and due to this the raw material fed, has around 8 o/o of total solid materials in dillution (water and/or inoculous material). It is fed with manure from 8 to 10 semi—stable cows or the equivalent in other animals; this could be mixed with wastes from harvests and a compound can be prepared in such a way that it will disgregate the organic material.

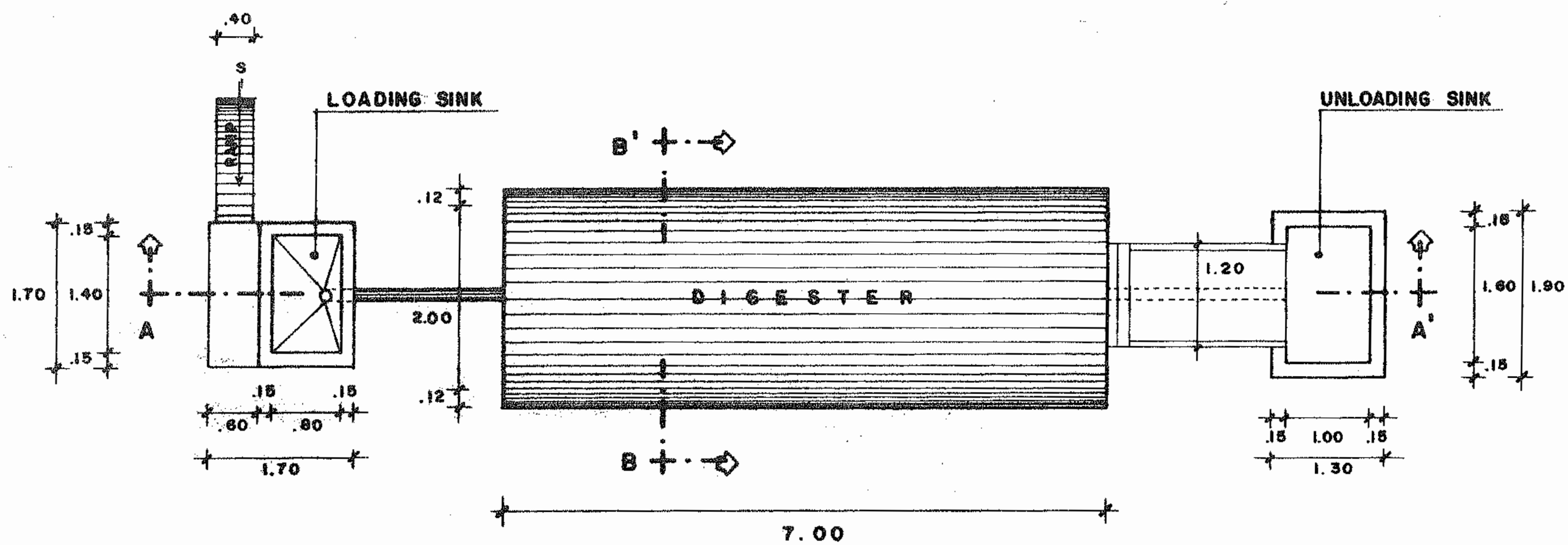
### 4.5 OPERATION OF THE DIGESTER

Loading is done in a continous or semi—continous form, through an entry chamber, feeding it the first load with pre—compound material preferably.

During the first load it is necessary to introduce the inoculous material, with the purpose of accelerating de—composition of the organic material, and therefore the gas production.

The digester is loaded every day with a mixture volume determined previously and the same volume is extracted by communicating receptacles towards the unloading sink, avoiding the utilization of pumps.

The overflowing device, besides being an unloading alternative, is also a water seal that works as a relief valve in case the internal pressure will overpass the maximum permissible pressure.



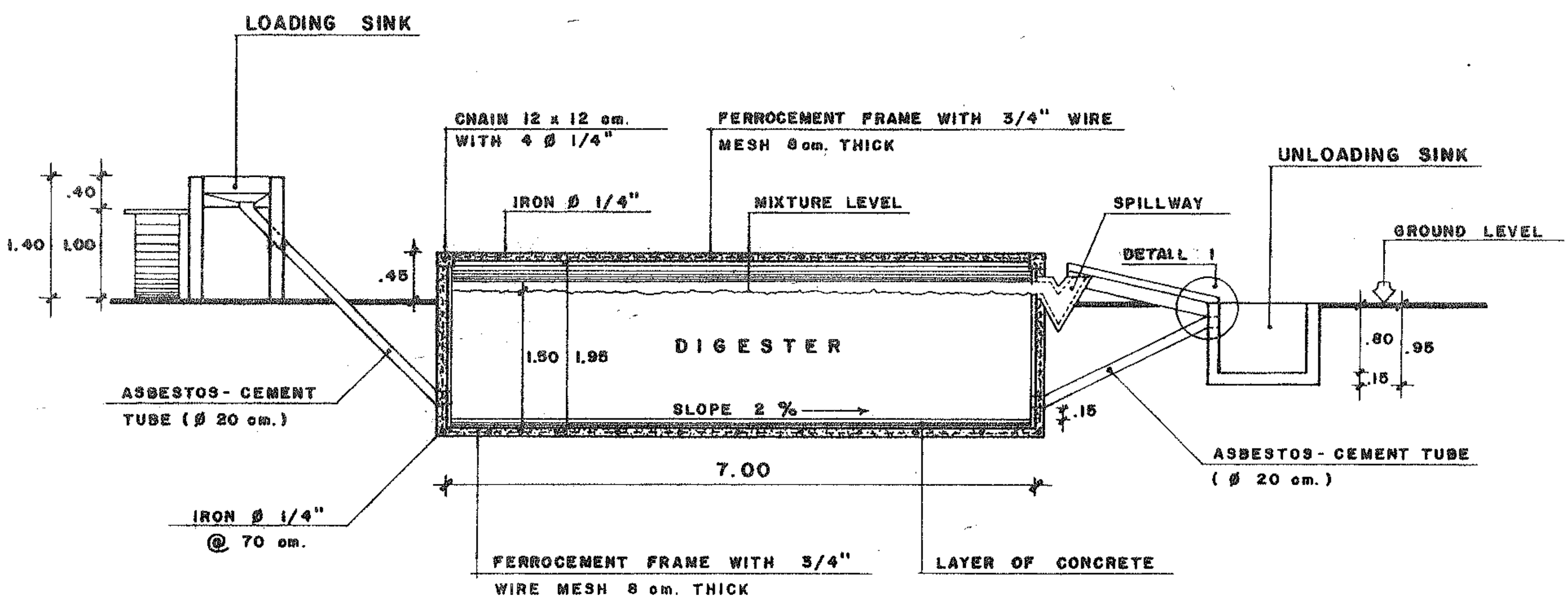

## GENERAL PLANT

SCALE: 1.75

olade

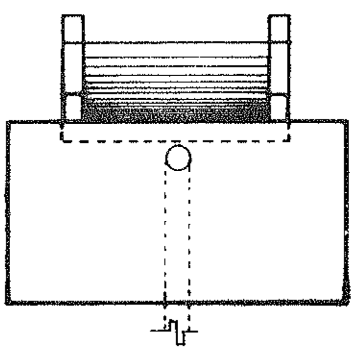
project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: PLANT | scale: INDICATED |
|---|---|---|
| 1 | capacity: (inside) 10 m3. | type: IIE-MEXICO |




CROSS - SECTION A - A'

SCALE. 1 : 75

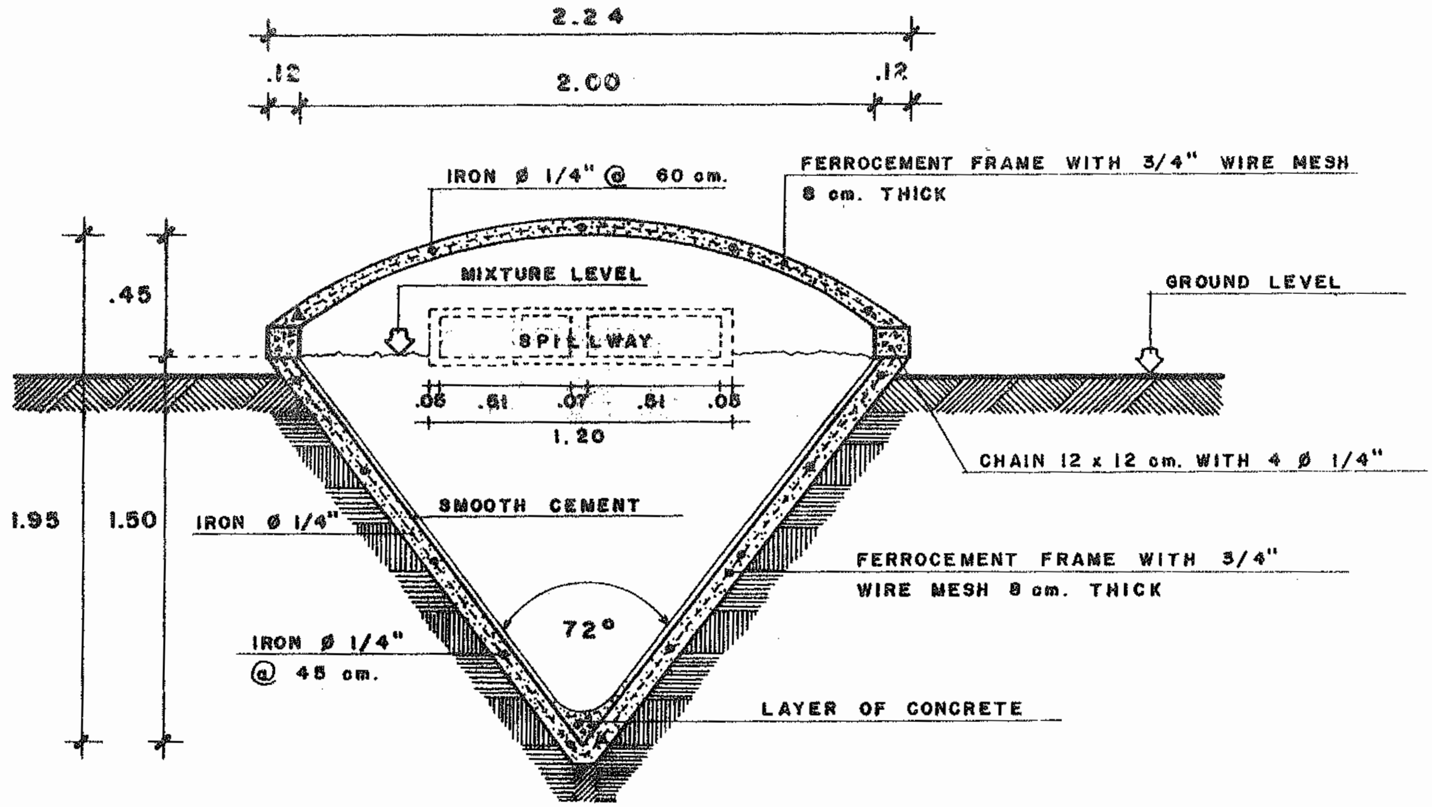


DETAIL I

olade

project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: | scale: |
|---|---|---|
| 2 | CROSS - SECTION | INDICATED |
| | capacity: (inside) 10 m3. | type: IIE - MEXICO |

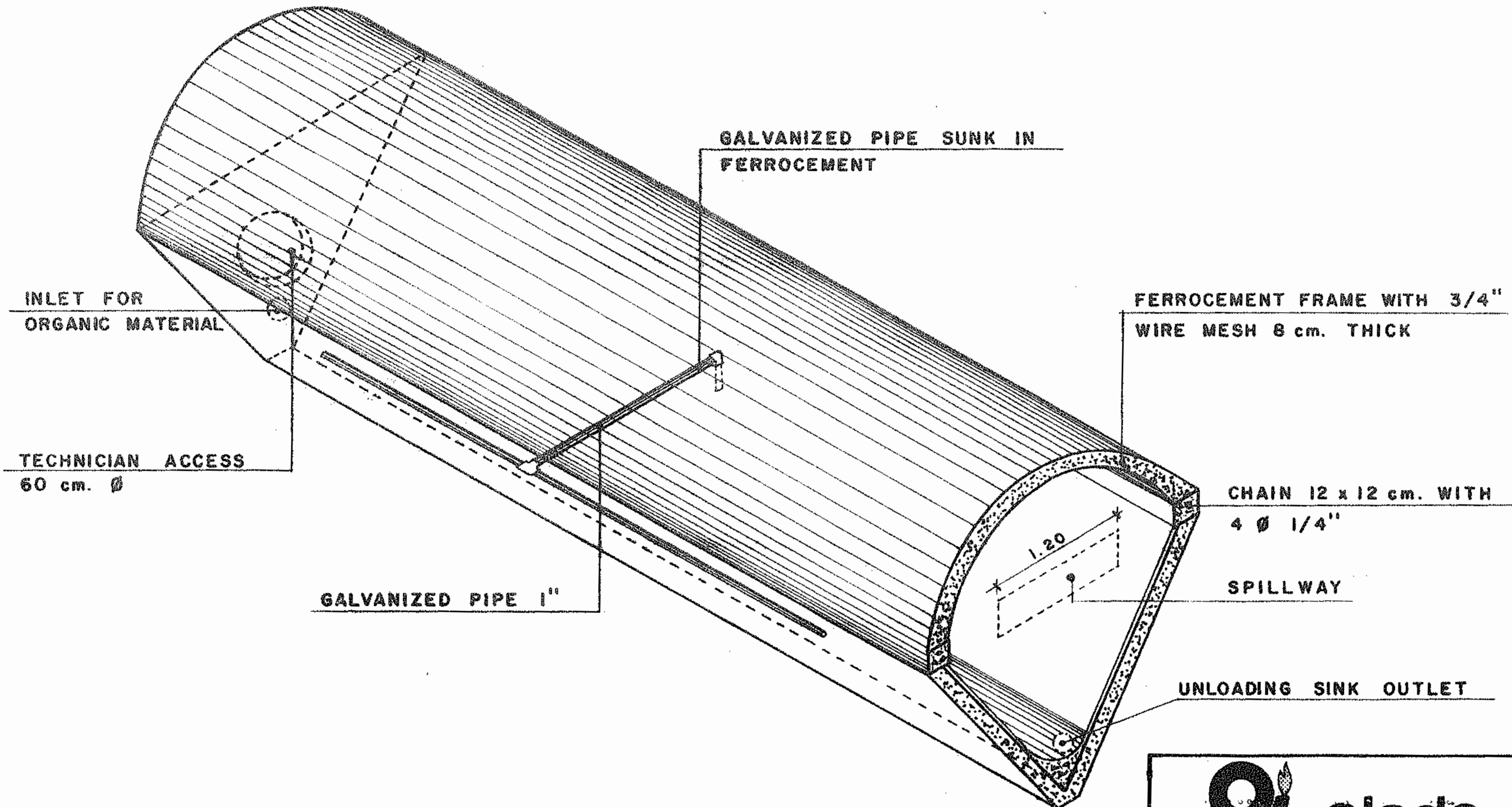



## CROSS- SECTION B-B'

SCALE. 1 : 30

olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 3 | contains: CROSS-SECTION | scale: INDICATED |
| | capacity: (inside) 10 m3. | type: IIE-MEXICO |

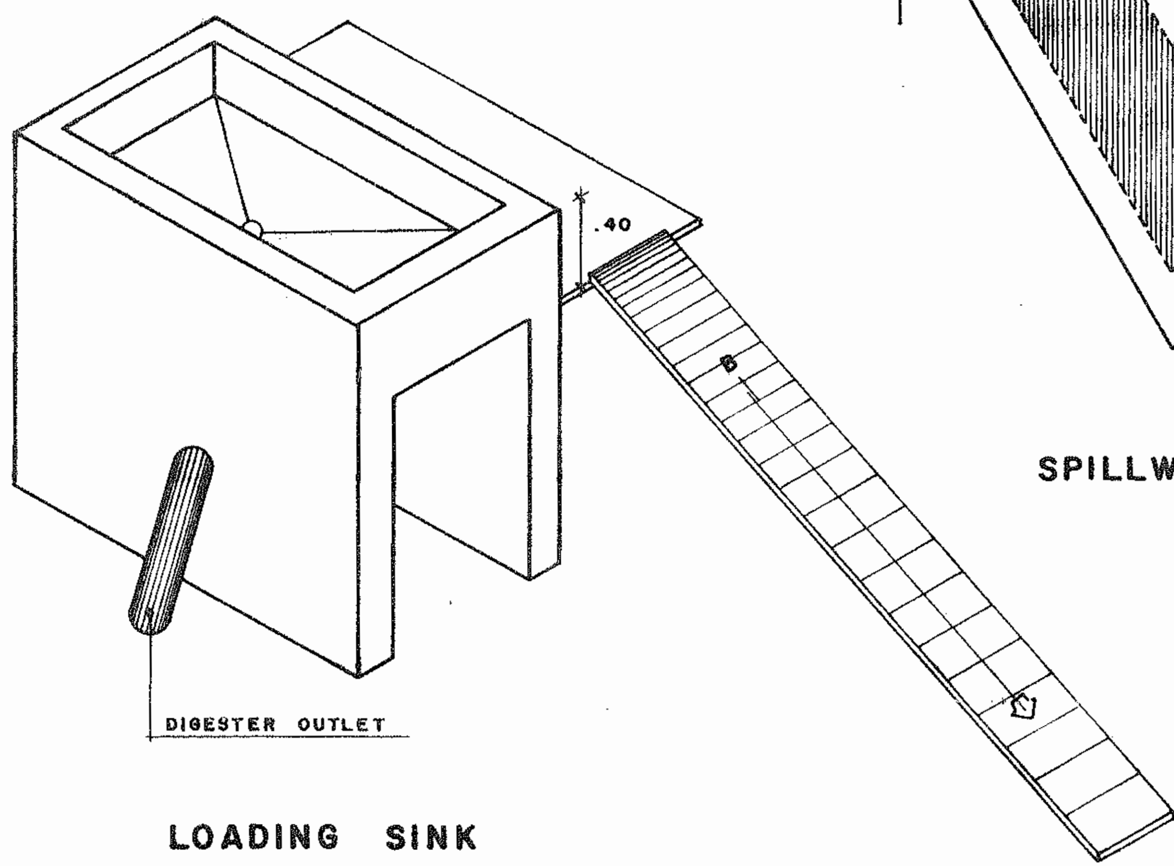



DIGESTER ISOMETRY

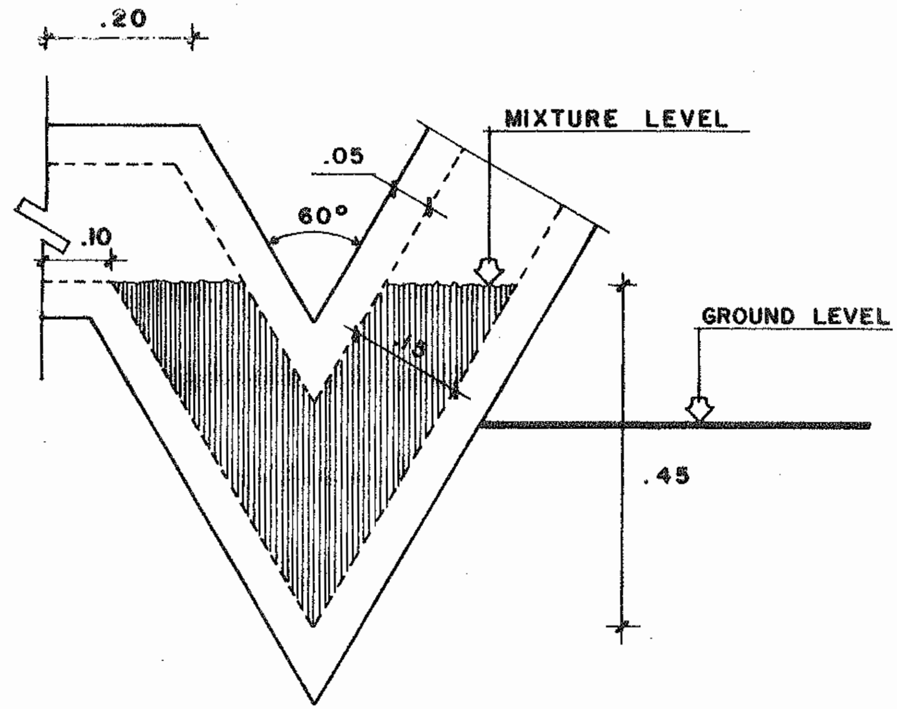
olade

| | | |
|---|---|---|
| project: FERROCEMENT CONSTRUCTION DETAIL | | |
| PLATE 4 | contains: PERSPECTIVE | scale: |
| | capacity: (inside) 10 m3. | type: IIE - MEXICO |

ISOMETRY




LOADING SINK




SPILLWAY DETAIL SCALE. 1:10

olade

project: FERROCEMENT CONSTRUCTION DETAIL

| PLATE | contains: | scale: |
|---|---|---|
| 5 | DETAIL - PERSPEC. | INDICATED |
| | capacity: (inside) 10 m3. | type: IIE - MEXICO |

## 4.6 UTILIZATION OF THE DIGESTION PRODUCTS

The gas is taken by a pipeline directly for its utilization, either for cooking purposes, illumination by lamps, or to move motors of internal combustion. It must be taken into consideration that if a separated gasometer is not designed, this design will not permit to obtain gas at constant pressure. Therefore, it is recommended to have a regular consumption with the purpose of avoiding big pressure fluctuations.

The efluent that is separated each time the digester is loaded, is utilized directly in agriculture, and it is not advisable to storage it for a long time. The production efficiency is improved if the efluent is backfed periodically through the loading sink.

The efluent could also be utilized for aquaculture or for poultry feeding.