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海外技術協力事業団

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CONTENTS

PREFACE

A survey of a model field for readjusting farm was undertaken by the Agriculture & Forestry, over a five-year period starting from 1963, with the purpose of establishing the standard for readjusting field so as to adapt it to the mechanization of farm management in the future. In this, as an agency was necessary who makes recommendations and examinations about the details of investigation into the model field and visits the field to direct the survey in the place, the Agricultural Civil Engineering Society with such tasks. As it was just the time when the Government had started concentrating a great effort on the readjusting project of basic land as the most important support for the modernization of agriculture and on the other hand, in the area of science, a desire was pressing to establish a knowledge of the agricultural land land planning capable to cope with the new change in managerial environment, the Society willingly accepted the trust. The Committee of Model Field for Farm Readjustment was set wp in the Society to perform these tasks; since then they have been reappointed every year and their activities are still continued today. The surveys on the model paddy fields set up in three districts in 1963 were completed in five years as originally sceduled. (The model dry field was set up in 1965 under a seven-year program and the survey for the fourth year is under way.)

Therefore, the contents of this report relate only to the surveys of model paddy fields among those of model fields the Society was entrusted with.

The tasks of the Committee being as aforementioned, the final report submitted to the truster at the end of March in 1968 from them (a subcommittee in charge of the model paddy field was particularly designated as Paddy Field Group) was fairly voluminous one comprising the following three parts:

Part I The Compilation of Findings

(1) The Compilation of Findings by Districts

(2) The Compilation of Findings by Items

Part II Tentative Plan of Standard Type of Field suitable for Farm Management mechanized by Large Machinery

(1) Assumption

(2) Tentative Plan and Its Application

Part III Problems left Open

This report deals with only the Part II of it (and that in a brief of a part of it) on account of limited space. This is because it was believed that the present purpose would be served by reporting what kind of technological knowledge was derived (or could not be derived) from those findings.

At first glance, as you see in the text, this part of the report takes the same style as that of the draft of the planning standard for land improvement project adopted commonly by the ministry of Agriculture & Forestry. But, it is earnestly wanted to remember that the said point by no means suggest a direct relation between this report and the said draft of the planning standard. Although it is true that the compiling of this part of the report in the present style was attributable to the writer's sincere desire to make the contents of the committee report serve as far as possible for any revision of the planning standard for land improvement project someday, it was more attributable to his opinion that any systematization of technological knowledge ought to take a form of "instructions" or "criterions".

As you may see from the title of Part II of the abovementioned report, the object of the survey was at all times restricted to "a paddy field capable of adapting to farm management by large machinery". It was nothing but that an examination from such viewpoint was demanded for at the outset, in the general idea of the survey (published in August, 1963). Probably it was due to that the Ministry of Agriculture & Forestry at those days in 1963 had not any established standards as to what conditions should be satisfied in respect of block of paddy field layout of roads and bearing capacity of ground foundation in order to make the technique of farm management with large machinery function efficiently, and that such conditions were believed to be useful to fix a target for forming those standards in future.

For this reason, the writer, standing upon these facts, decided at first what types of large farm-machineries should be taken into account, what topographical conditions be presumed, what cultural method be applied and what operating method be adopted; then he put to himself a question "if such conditions were assumed to exist, what character a paddy field should have in order to be most suitable to them." The writer tried to answer the questions on the survey of the model fields over a five-year period and his answer is set forth in the text of this paper.

Paddy Field Model District covered for the Survey

District	Location	Area of model field	Land conditions (at present)			Outline of readjustment		Farm machineries introduced after readjustment
			Topographical gradient	Soil	Other features	Size of block	Others	
Nojiri	Fukumitsu-cho, Toyama Prefecture	46 ha	1/200-1/300	Surface soil - loam Subsoil - gravel	* Shallow top soil area. * Alluvial cone on the riverside of Shokawa, with low groundwater level of 5-10 m. * Dispersedly residing area.	Farm block; 30m x 200m	* No sub-drain.	* Tractor (20-45 PS) * Combine (harvesting width:2.8m) * Binder (3-4 row harvesting) * Border sprayer * Grain drill
Tokasu-wanaka	Kaizu-cho, Gifu Prefecture	29 ha	1/10,000 - 1/18,000	Loam - clay loam	* Polder area between Nagara River and Ibi River of around 0.1 m in altitude, with very low temperature.	Farm block= field block; 125x600x680m	* Pipe irrigation system by combination irrigation drainage pump * Sub-drainsare buried.	* Tractor (35-45 PS) * Combine * Border sprayer * Grain drill
Mizuma	Mizuma-cho, Fukuoka Prefecture	42 ha	1/1,000	Clay loam	* Mud area on the downstream of Chikugo River of soil with poor drainage condition and small land resistance.	Farm block= field block; 50-90x200m	* Small drains are built along the longer sides of the blocks. * Sub-drains (combined projectile culvert) are buried.	* Tractor (37-450S) * Combine (harvesting width: 2.3-3.1m) * Bordea sprayer * Grain drill

I ASSUMED CONDITIONS

1. District covered for the Survey.

(1) An area equal to a larger section of a village will be assumed as a condition.

(2) The larger section will comprise several hamlets each having area of 30-50 ha.

(3) The hamlets will have a concentrative residing pattern.

(4) The topography of the district will be a flat land with gradient of less than 1/500.

(5) Any special assumption will not be made on climatic and soil conditions (soil texture and quality).

2. Managerial Conditions (Production Structure).

(1) The production scale will be expanded virtually by promoting joint use of land even if the constituent units are small.

(2) Large machinery and facilities will be equipped by joint investment and be used jointly.

(3) Seedling cultivation, tillage, land readjustment, protection against insect damage and harvest will be performed wholly by joint work.

(4) However, facilities capable to control surface water by farm blocks and those capable to control groundwater by field blocks or unit field blocks will be designed.

3. Crops.

(1) Summer crop will be paddy and winter crop will be barley.

(2) The target of crop yield will be to attain the present level at least or a higher level.

4. Farm Work System in Paddy Cultivation.

(1) Large tractors used for tillage and land readjustment will

be those of wheel-type 40 PS class. However, it is assumed to apply tillage rotor-vator cultivation but not plow cultivation.

(2) Protection against insect damage will be performed by means of surface sprayer, but aerial spraying by a helicopter will not be assumed. Such surface sprayers as tractor-drawn Speed Duster with effective spraying width of about 100 m on each of both sides and tractor-drawn Border Sprayer with that of about 30 m on each of the both sides will be used independently or concurrently.

(3) Harvest will be performed by medium-sized combine of semi-crawler type with harvesting width of 3 m.

(4) Road conveyance of farm materials and crops will be performed by tractor-drawn trailer.

(5) As to the method of paddy cultivation, it will be able to adopt either if direct sowing dry or flooded paddy field and mechanized transplantation of seedling.

Bases of Assumed Conditions

1. District covered for the Survey.

(1) An area equal to a larger section of a village will be assumed as a condition.

[Basis] It is natural that a land which is selected for field readjustment has certain extent of area. Therefore, the tentative plan for the standard type of a district selected for the above purpose needs to be formed on the basis of the area of such district. The assumed area to be deemed enough for forming the standard type is such that covers the immediate problems arising in connection with the purpose. That is, the smaller area will simplify to form the tentative plan, though, on the other hand, there is a fear that it will not cover all the problems confronted with in a wider district. However, excessively large area will make it necessary to consider the relation with cities or other industry (in respect of land use and water use), resulting in more complicated conditions.

In the assumed conditions here, the object of consideration is set at an area equal to a larger section of a village. In fact, the areas of such larger sections are not necessarily of defined in our country, but basing on a practical judgement that several hamlets (each of scores of ha) make a larger section and several larger sections make a city, town or village (of several thousand ha), the area of a larger section is estimated at about several hundred ha because the area of this magnitude is believed to suffice for dealing with all problems arised in relation to the formation of standard type for field readjustment.

(2) The larger section of a village will comprise several ham-

lets each having area of 30-50 ha.

(Basis) The reason why the hamlets each having area of 30-50 ha are deemed as the constructural units is that these areas are believed suitable as those of basic units, in view of effective operation of mechanized technique system based on a wheel-type 40 PS class tractor, as assumed in 4-(1) below.

The hamlet as a unit is not only the working unit based on a large tractor as its nucleuse but the fundamental working unit of joint work, joint use and irrigation and drainage; it is as well the fundamental unit of settlement of accounts when the transfer to the perfect joint management is made in future.

The larger section of a village as mentioned here will comprise several of those hamlet. Accordingly, the area of the larger section will be about 150-300 ha. That is, the hamlet is a fundamental production unit depending on one large tractor as a rule, but since the proper load area of a farm machinery varies according to its type, it is more effective to make machinery available on the basis of the least common multiple group (a group consisted of several hamlets). Also, considering any breakdown of the tractor or farm machinery, and from the viewpoint of diversification of risk as well, it is advisable to devise a system in which several units make use of them in association with each other.

It is anticipated that, with the enlargement of facilities (in particular, facilities for drying, processing and warehousing of products or machinery maintenance shop), the associated group will be necessitated to expand to the size of a larger section of a village as a unit for joint investment and use of facilities such as those which one hamlet can not own alone. It is further expected that, depending on what course the joint operation will take, the larger section will have a mechanization center which owns several tractors, other machineries, combines and production facilities to play a role as the center of joint use of machinery and facilities in such larger section as a whole.

The larger section of a village which is a community will form an integrated body in regard to daily life facilities (such as waterworks, meeting place, day nursery and daily necessaries market). In addition, several of such larger sections will cooperate to form a comprehensive center which includes agricultural cooperative association, land improvement district, city, town or village office, school and hospital.

(3) The hamlets will have a concentrative residing pattern.

Basis The reason of assuming a concentrative residing pattern in which clusters of group residential quarters of 30-50 ha are districuted as if a network is entirely for convenience' sake because such pattern is familiar in the flat land paddy fields in our country and the units of joint operation can be more easily formed under the concentrative resinding system rather than the dispersed residing system with individual residence distributed in the district, if a hamlet is to be regarded as a fundamental production unit.

(4) The topography of the district will be a flat land with gradient of less than 1/500.

(Basis) This is a result of judgement that if the gradient is less than 1/500 cut and filling earthworks will not constitute a restrictive condition to the formation of the standard type of field.

(5) Any special assumption is not made on climatic and soil conditions (soil texture and quality).

[Basis] The climatic and soil conditions must be always taken into account when readjusting a field as they have great influences on dry and wetness of paddy field, actual working days and hours operation efficiency of various works and machinery but since these influences take place in a very complicated manner, they are considered in [Explanation] at need rather than simplifying them by defining only one case extracted from them to include it in the assumption. However, such climatic conditions as extremely heavy snowing and cold weather and such particularly bad soil condition as peat, mud and sand, which are found in Hokkaido and a part of Northeastern District, are not assumed as conditions in this tentative plan.

2. Managerial Conditions.

If conditions are not assumed as to what kind of farm management will be carried out on the field of which readjustment will have been completed, there will emerge various plans about the standard type of paddy field suitable to mechanized operation as so said in a word, resulting in that any standardization will become difficult after all. Thus, it is inevitable to assume certain managerial conditions to the extent of necessity for preparing the tentative plan. Furthermore, any managerial conditions to be assumed should not be a pure fabrication having no possibility of realization nor, on the other hand, be forgotten in the reality in which no evolution for the future can be expected. Accordingly the conditions are assumed as follows.

(1) The production scale will be expanded virtually by promoting joint use of land even if the constituent units are

small.

[Basis] The agricultural production of our country is supported by the management depending on household labor based on petty land ownership. Therefore, the reality must be assumed as the conditions for forming a general standard type of paddy field. Moreover, it is not anticipated that this production structure existing actually will transfigure in the near future. For the present purpose, it is deemed that the standard type of paddy field on the assumption of such reality has been established in a way through the historical experience in block reform during the past 60 years (see, for example, "The Block Reform of Cultivated Land" by Niizawa and Koide), and it is presumed here that a joint management will be effected to the extent suitable for mechanized management. In respect of the land, it means that the production scale will be expanded by promoting the joint use of land with the petty land ownership preserved. However, the joint ownership of land is not assumed as a condition.

(2) Large machinery and facilities will be equipped by joint investment and used jointly.

[Basis] Since the large machinery and large facilities are not so tightly bounded by the usual ownership as the land, those which are to be newly introduced into the management will be aquired by joint investment (that is, joint ownership) and joint use of them will be made. However, there may be mixed scales of joint units formed by a larger section of a village, or city, town or village in accordance with the kinds, sizes and the using systems of machinery and facilities. Some of small machinery and small facilities (for example, bicycle-drawn trailers, motorcycles, garages, manure barns and lumber rooms) will be owned and used individually.

(3) Seedling cultivation, tillage, land readjustment, protection against insect damage and harvest will be performed wholly by joint work.

[Basis] If the labour means such as land, machineries and facilities increase in size and are operated jointly, it is natural to expect the labor to be organized jointly. In fact, the type of joint management differs according to whether the labor is served by each household or provided by full-time worker.

Since it is deemed that this difference will not cause any variation in the standard type of paddy field, any definite labor type is not assumed specially. If it causes any difference in the standard type it will be considered in the Explanation .

(4) However, facilities capable to control surface water by farm blocks and such capable to control groundwater by field blocks or unit field blocks will be designed.

[Basis] In the case of individual management, it should be a principle that the control of surface water and groundwater is capable by farm blocks in order to meet the requirement of a petty managing agency. On the other hand, in the case of joint management, it is apt to deem it enough if the control of water is capable by blocks of wider area; however, with joint management as assumed, the control of water is presumed to effect in a fairly narrow field due to the following reasons.

In order to reduce the labor peaks in busy seasons of spring and autumn, it needs considerations in the light of cultivation practice such as combinations of species (early, mid-season and late varieties), of direct sowing and transplantation and of one-crop and two-crop fields. Each of these requires irrigation and drainage different one another. In addition, if the crop yield on the present level or above it is to be expected as is assumed in 3-(2), the irrigation and drainage for insecticide application, manuring and intermediate drying of field will have to be managed delicately. Since the land is not owned jointly under this assumption though the joint use of it is made, it is desirable to control both the surface and subsoil water by unit field blocks, taking account of the fact that the products are vested in the ownership of individual management. However, it should be easier for some blocks in a field to have the same irrigation and drainage system by means of the control of cultivation practice where the jont use of machinery is assumed rather than the management is broken up into individuats. Therefore, taking account of the control of surface water by unit field blocks on the one hand, the control of the groundwater which is very difficult to carry out by small blocks will be effected by field or farm blooks instead of unit field blocks.

For reference: The categorical division of joint farm management. The type of joint operation assumed in 2 above can be classified in the joint work type by joint facilities (where all households serve their labor) or the association contracted work type (where all-time workers engage in it) accordingly to "Categorical Division of Joint Farm Management" by T.Watatani, General Study of Agriculture, Vol.16-3, July, 1963. Where the management organization covers the all process of production sphere it is classified into the centralized land joint operation type.

3. Crops

(1) Summer crop will be paddy and winter crop will be barley.

[Basis] In the present situation of our country, most of the paddy fields are used for only one-paddy-crop-per-year because of managerial conditions and others, though the climatic conditions permit to cultivate the winter crop. Here, it is not restricted to the one-paddy-crop system in consideration of intensifying the land use as far as possible. Accordingly, a standard type of paddy field should be considered assuming the cultivation of only on-paddy-crop in the case of a district where the winter crop is entirely impossible due to the climatic conditions. This point will be referred to in "Its Application".

Although the winter crops involve not only barley and wheat but rape-seed and beans as well as green manure crop and pasture harvested in green leaves, the crop is assumed to be barley cropped in grains. It is because such assumption will require more strict conditions of the field than presuming any other crop. The local crops such as tulip and rush are also excluded from the assumption. They will be referred to in "Its Application" at need.

(2) The target of crop yield will be to attain the present level at least or a higher level.

[Basis] Although the paddy field mechanization is apt to be discussed only from the standpoint of labor saving, it is required, from the viewpoint of the self-supplying structure of foodstuff in our country, to dimish the dependence on the foreign foodstuff at least by maintaining the annual crop yield and if possible by aiming at the annual crop yield exceeding the present level. This may be fairly severe conditions from the standpoint of the field readjustment and yet it will be included in this assumption.

4. Farm Work System in Paddy Cultivation.

(1) Large tractors used for tillage and land readjustment will be those of wheel-type 40 PS class. However, it is assumed to apply tillage rotor-vator cultivation but not plow cultivation.

[Basis] The reason why the use of large tractor of wheel type is assumed and not that of crawler type is to show the aim, that is to improve the arable land conditions to the extent of the wheel-type tractor being able to run and operate adequately. In this connection, it is not denied to use any supplementary device to increase its manoeuvrability in the wet and weak land conditions.

It needs to give the size of farm operation tractor as a due prerequisite prior to setting the arable land conditions. The size of 40 PS class assumed for the present purpose is an average size of tractors of 30-50 PS classes which are believed to be increasingly popularized recently for use in farm management. The horsepower of tractors will further increase in future, but it is a controversial question impossible of prompt decision whether this trend will bring about any increase in size and weight of tractor, resulting in a demand of more severe conditions on the arable land. Although it is presumable that tractors larger in horsepower and smaller in weight and size than the present ones will be explored in the course of the future development of machinery the tractors presumed here are those of 40 PS class now on the market. It is also assumed to use work machinery generally on the market.

There are rotor-vator cultivation and plow cultivation for performing the tillage work by a large tractor, and the latter cultivation demand more severe conditions on the shape and size of the block and the bearing capacity of the ground foundation. However, as it is deemed sufficient for the plow cultivation to be executed once every 3-4 years, the conditions of the arable land will be determined in consideration of rotorvator cultivation only and any problem arising in the case of the plow cultivation be mentioned in Explanation .

(2) Protection against insect damage will be performed by means of surface sprayer but aerial spraying by a helicopter will not be assumed. Such surface sprayers as tractor-drawn Speed Duster with effective spraying width of about 100 m on each of both sides and tractor-drawn Border Sprayer with that of about 30 m on each of both sides will be used independently or concurrently.

[Basis] The assumed group residential quarters of concentrative resideing system make it more easier to perform aerial insecticide spraying than dispersedly residing system. As it is believed that there are many problems of technical and economical nature in the execution of all the works protecting against insect damage only by aerial spraying, with the crop yield kept on the present level, the use of a surface sprayer is assumed here. It does not deny to adopt the aerial spraying partially, but it means the conditions of arable land are adjusted so that the surface sprayer can be used.

The surface sprayers are available in two types, that is duster type and liquid agent sprayer type, and their effective spraying width on each of both sides is assumed respectively to be 100 m and 30 m. The liquid agent sprayer type shall have a hose of 100 m in usable length. These represent the standard figures in view of the machinery capacity and spraying labor. It should be noted that these figures do not necessarily indicate the critical capacities of existing machinery and they may be fairly increased according to how the machinery are used. These figures must be considered carefully as they are to bring a great difference in the standard type of a field. Though the border sprayer directly mounted on a tractor is available, the tractor-drawn type which imposes more severe conditions on the standard type of the road will be adopted here.

(3) Harvest will be performed by medium-sized combine of semi-crawler type with harvesting width of 3 m.

[Basis] Considering the autumn climatic conditions in our country, the use of semi-crawler type of medium size (with harvesting width of 3 m) will be assumed as a condition. Where the joint use of combine is assumed, the small type (with harvesting width of 2 m) will be inadequate in its efficiency in relation to harvest season and standing operation hours, and the large type (with harvesting width of 4 m or more) has drawbacks that it necessitates to widen the road width and improve its structure for the only purpose of running of combine. It will be reasonable to assume the use of medium type though it may have still some difficulties in the light of the real conditions in out country.

(4) Road conveyance of farm materials and crops will be performed by tractor-drawn trailer.

[Basis] In carrying farm materials or crops, the change of carrying means by using a truck and a trailer respectively inside and outside of the field may be conceivable where the conveyance distance is so long that the time of trans-loading may be recovered by such practice. If one rice center is provided in the district (200-300 ha at the most) equal to that of a larger section of a village assumed here, it will be more economical to carry the grain by trailer throughout the inside and outside of a field. Still more, where return trips between the hamlet (30-50 ha) and the field are assumed, it may be said that the trailer is more advantagecus than the truck. In any way, it is not intended to discuss their merits and demerits to reject the truck. The reason why the use of the trailer is assumed is that the trailer imposes more severe conditions on the standard type, which should enable the use of the truck too.

(5) As to the method of paddy cultivation, it will be able to adopt either of direct sowing dry or flooded paddy field and mechanized transplantation of seedling.

[Basis] The direct sowing method of paddy cultivation in our country has not yet gotten out of an experimental stage with its diffusion rate accounting for only 1.02% of paddy cultivation as of 1966. So long as the transplantation of seedling presumes the planting by hand, it seems to be gradually replaced with direct sowing in view of the inhumanly heavy labor required for hand planting. On the other hand, the development of rice planting machinery is under way and a technique such as transplantation of young rice plant which can replace the hand transplantation taking account of the possibility of mechanization is also being developed. It will be an effective measure to adopt seedling transplantation and direct sowing on a suitably mixed basis in order to reduce the labor peak in the spring season. Where a winter crop is cultivated, seedling transplantation is the method naturally safer than direct sowing.

The direct sowing method includes the flooded field system and the dry field system, each having its own characteristic. Either one or both of them will be applied independently or concurrently in accordance with the conditions of each district and management.

Seeing from the above description, in our country it will be enough for the time being to readjust the paddy fields presuming the hand transplantation. Eventually, it is anticipated that, with the gradual introduction of dry or flooded field direct sowing thenceforth, three methods, that is mechanized transplantation, dry field direct sowing and flooded field direct sowing by means of rice planting machinery and the like will be executed in parallel with each other, keeping a certain rotation system; accordingly, a standard type of field capable to adopt either of these method will be considered here.

A. Connection between Field and Outside Area.

> Facilities such as machinery shed, repair shop, drying and adjusting facilities, storehouse and parking area will be grouped to locate at the peripheral part of a group residential quarter; these facilities and the fields will be connected by farm village community roads if possible, or otherwise by trunk farm road.

[Explanation]

1. If joint production facilities are located in the group residential quarter it will increase the traffic volume of heavy goods in the quarter, with noise and dust causing a nuisance.

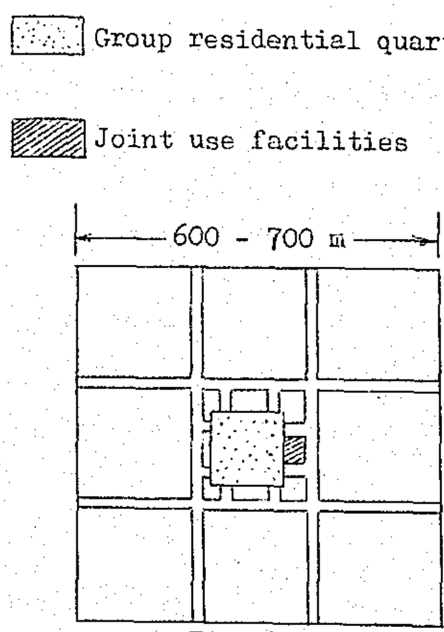


Fig. 1

Therefore, it is desirable to locate these facilities grouping together near to the peripheral part of the quarter, and possibly at about the center of the fields.

2. Farm roads are classified into the following four kinds based on their respective functions.

(a) Farm village community road - It is used for marketing and selling of agricultural products and purchasing of fertilizer and other farm materials as well as for community life in farm village.

(b) Trunk farm road - It connects the arable land with the mechanization center, the drying and adjusting facilities and the farm storehouse and it has a large traffic volume.

(c) Branch farm road - Cultivation road: It is a road necessary for cultivation such as tillage, insecticide application and harvest.

Connecting road: It is a road used for transfering the work from field block to field block, for drawing water from branch canal to ditches and for going the rounds of water. The width of each class of these roads in described in C-1 below.

3. In many cases, the farm village community roads is existing concurrently with a group residential quarter, forming the outer frame of a field shape (a typical example is the square reclamation road of 545 m in each side to be seen in the paddy field zone in Hokkaido). Since the existing community roads with many curves and insufficient width will eventually distort a field shape, they must be improved or widened. Class 2 farm road will be good for connecting between group residential quarters (see C-1), but when the road passing through a quarter has large traffic volume a detour route should be provided, if possible,

and its width be increased to that of class 1 farm road (see C-1). Apart from this, it needs to consider the necessity of building a ring road to connect various farm roads with each other at the outskirt of the entire district.

B. Layout of Irrigation and Drainage channels and Farm Roads in Field.

B-1 *Layout of Irrigation and Drainage channels and Farm Roads.*

1. Main irrigation canals and main drains will be arranged as shown Fig. 2 and Fig. 3. The selection between both systems will be determind chiefly based on the topographical conditions. 2. Branch irrigation canals and branch drains as well as their respective tributaries will be arranged as shown in the figures, with the principle being to separate irrigation and drainage completely. 3. Farm roads will be arranged along the main, branch irrigation canals and drains and the irrigation ditches. Also they will be built along small drains in any case where they are needed for the insecticide application.

[Explanation]

(1) Basic Idea of Layout

The framework of a paddy field readjustment project presumes to determine the location of the main irrigation canals in the district.

Where there is a slight unevenness in the topography of the district, the main canals are arranged on the higher part, as a rule, and the main drains on the lower part (see Fig. 2). On the contrary, where the topography is flat and even, the main canals and the main drains are located along the both sides of the road (see Fig. 3).

As to branch canals and drains and their tributaries, there are two systems as shown in Fig. 2 and Fig. 3; that is, ditches and small drains depart from the branch canal and drain to the one side of it (as exemplified in Fig. 2 or to the both sides of it (as exemplified in Fig. 3).

Farm roads are arranged, as a rule, along irrigation and drainage channels.

In general, location, regime and improvement of river have close relation with the drainage planning; excess and deficiency of irrigation water resource, location and method of water intake and water use practice have close relation with the irrigation water planning, and the present situations and projects of national roads, prefectural roads and city, town or village roads have close relation with the farm road planning. Therefore, in forming these plans it is necessary to examine thoroughly the relation between the present situations and the future projects in these wider regions.

(2) Irrigation and Drainage Channels Networks

The drainage control of paddy field on a flat land is a important factor of paddy production and of improved use of paddy field. Particularly, in the water-logging or semi-water-logging paddy field zone where the groundwater level is high at all times, it is necessary to lower the groundwater level to make drying of paddy field. Therefore, the branch drains should be completely separated from the small drains and the facilities are needed to enable reasonable drainage control.

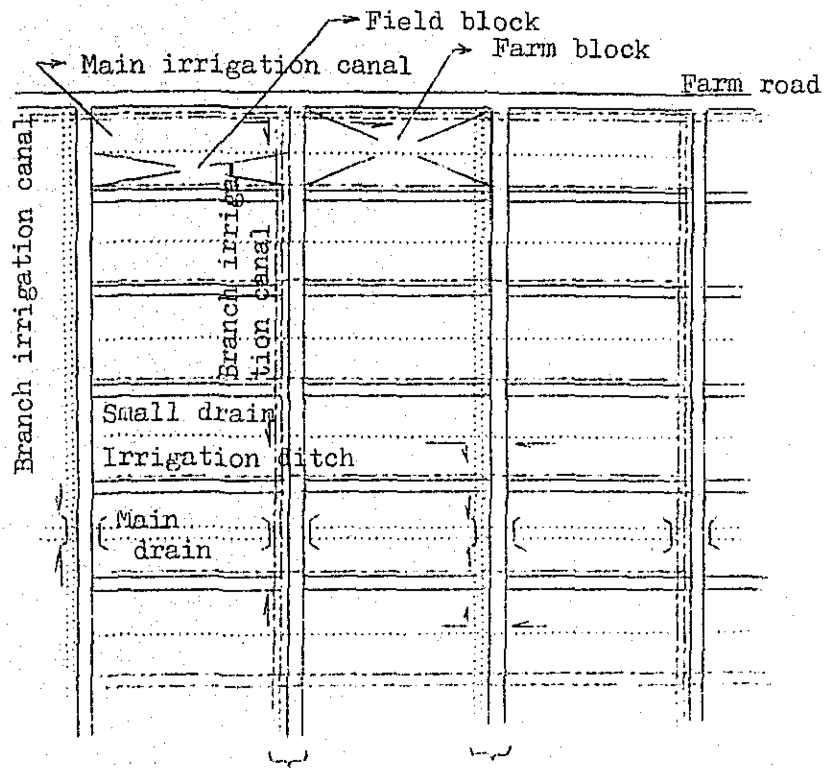
The branch canals and the ditches supply water to paddy fields through exclusive irrigation network. This exclusive irrigation network should not only supply the necessary quantity of water on the planned basis but be the facilities which enable good water control.

Although the water control requires the irrigation and the drainage to be separated from each other in their terminals, the general situation at present from the broader reginal point of view is that the water coming in the drainage channels from paddy fields is used again for irrigation purpose. Accordingly, it is necessary that the irrigation and drainage channels networks in the broader region is so organized as to enable to use water repeatedly for irrigation purpose; this is desirable from the stand-point of water use too.

The method to form such cyclic system of irrigation and drainage sometimes includes the use of pumping of water and pump drainage, and it needs to consider the adoption of pipeline in order to rationalize the water control and the water use.

General typical types of irrigation and drainage channels are shown in Fig. 2 and Fig. 3, though they are not necessarily adoptable in any case because of the natural conditions of the district concerned as exemplified in the following.

[Example 1] Fig. 4 shows the channel network of mizuma District, Fukuoka Prefecture, which has been planned with the emphasis laid on the drainage (surface and subsurface drainage) in the case of heavy clay soil with poor permeability. The paddy field blocks (field block = unit field block) are of about 200x75m (1.5 ha) - 200x100 (2.0 ha).



An example where a branch irrigation canal covers the both sides of a road.

An example where a branch drains covers the both sides of a road.

Main and branch irrigation canals

Irrigation ditch

Main and branch drains

Small drain

Farm road

Fig. 2 Type of Layout with main Irrigation Canal and Main Drain separated from Each Other.

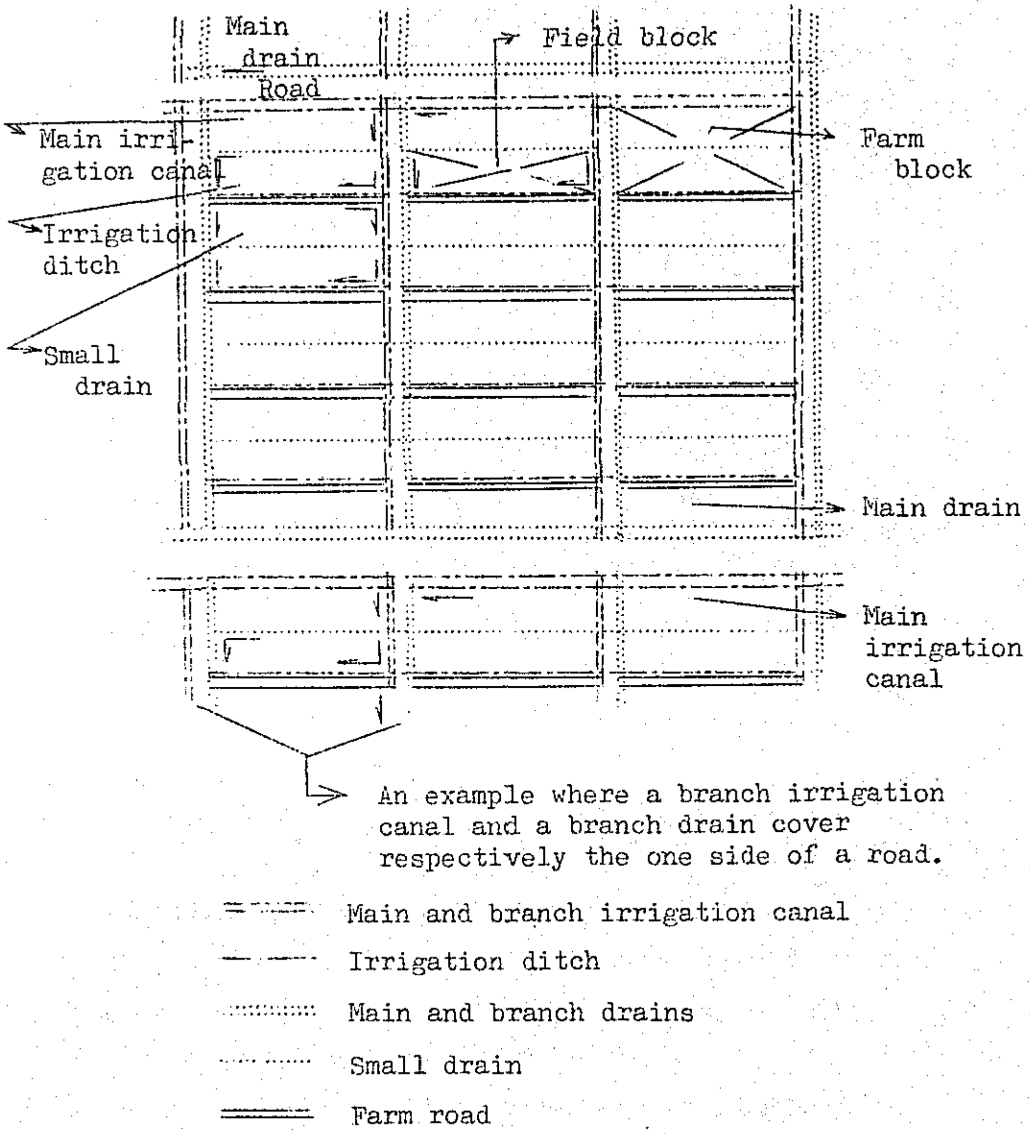


Fig. 3 Type of Layout with Main Irrigation Canal and Main Drain provided on the Both Sides of a Road.

The characteristic is that the irrigation ditches are built along the shorter sides and small drains along the longer sides, resulting in comparatively speedy drainage of ponded water on the paddy field surface. The small drains are connected to the sub-drain. The water is pumped up at the upstream side of the main drain.

[Example 2] Fig. 5 shows the channel network of Takasu district, Gifu Prefecture, which has been planned with the emphasis laid on the lowering of groundwater level and the draining of paddy field in the area where the subsoil water level is high. The paddy field blocks (field blocks) are of 600x125m (7.5 ha), and each block has no border in it. Two field blocks adjacent across a small drain make one farm block.

River Nakae serves as a water source and at the same time as a drainage river. The characteristic of the district is that irrigation and drainage are operated by the pumping station set up in each block. The drainage of surface water as well as groundwater in sub-drain is performed by those pumps. On the other hand, the said pumps take the water from River Nakae to supply it to paddy field as irrigation water through the pipeline buried under the road.

River Nakae as the water source serves as the drainage river in the broader region and at the time of its flood the water is drained into River Ibi by the pumps to regulate the water level, thus enabling the perfect water control by blocks by the operation of those pumps.

[Example 3] Fig. 6 shows the channel network of Nojiri District, Toyama Prefecture, which is located on the alluvial cone of River Sho with a gradient of 1/200-1/300 which is a little deviated from the standard of flat land.

The standard size of paddy field block (unit field block) here is 200x30m (0.6 ha). The characteristic of the district is that the soil is sandy loam, and the irrigation and drainage channels are provided along the shorter sides. In addition, since the district is sloping the channels (which are main channels as well as terminal channels) are combined irrigation drainage channels with weirs built at places to irrigate the paddy fields (except that the except that the exclusive irrigation channel along No. 3 Road is separated from the drainage channel built on the oposite side of the road).

In the district of such topography and soil the channel network of combined type is adequately attaining the purpose of water control. However, it is not impossible to compare its merits and demerits with those of the channel newwork of separated type.

To sum up, Example 1 and Example 2 show that the water is solely drawn from the main irrigation canal by pumping up and the water level of the drainage channel is controled to a certain extent.
The characteristics to be seen from Example 1, in respect of the water, is that a system for the repeated use of water is established through the main drains in a fairly broader region, and that from Example 3 is that the repeated use of water is made by smaller blocks in the district due to its topography, making it unnecessary to separate the irrigation from the drainage.

As to drainage, the main constituent of the channel is the main drains from which the irrigation water originates, in the case of Example 1 and Example 2; on the other hand, such main constituent is the combined channels serving as irrigation and drainage channels, incorporated in the main constituent irrigation canals, in the case of Example 3.

The existing channel networks of paddy field zones differ naturally, socially and historically in accordance with their respective times and methods of reginal topographies, water utilizations and flood controls, all of which have never been arranged for classification. Moreover, since the suitability of these conditions is the key to enable the rationalization of the water control, any plan should be formed on the basis of the possibility of the future development, adapting to the real situation, independently of formality, after thorough examination of the actual condition of water utilization in the district concerned and the broader region including it.

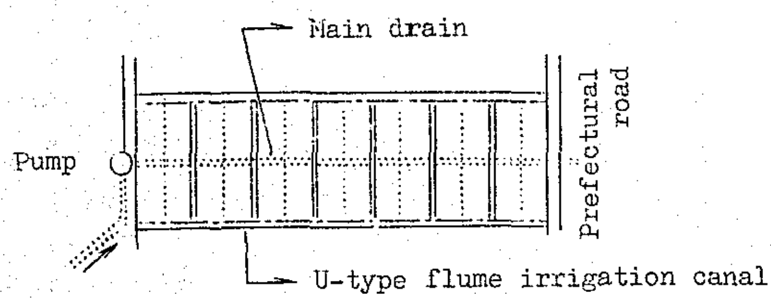


Fig. 4 Irrigation and Drainage Channel Network of Mizuma District (as a type specimen)

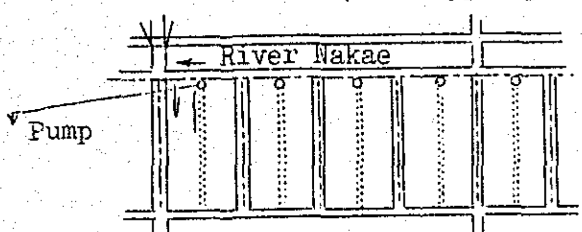


Fig. 5 Irrigation and Drainage Channel Network of Takasu District.

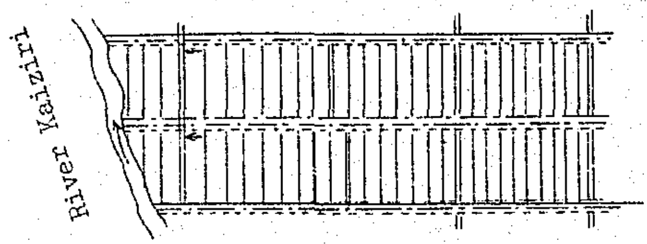


Fig. 6 Irrigation and Drainage Channel Network of Nojiri District.

(2) Road Network

The arrangement of farm roads in a field is planned, as a rule, in harmony with that of irrigation and drainage channels (fig. 2 and fig. 3).

In this connection, as branch farm road (cultivation road) is indispensable to farm works, it must be always built along any one side of a unit field block. It will be located along the shorter sode of a block to make economical use of land are, with its direction agreeing with that of the irrigation ditches and small drains. On the other irrigation ditches and small drains. On the other hand, the branch farm roads (connecting roads) are not necessarily dense in their frequency of use as a communication road under the joint operative condition. However, since the long sides of field blocks are restricted to 300-600 m by reason of irrigation and drainage as is mentioned in B-3, the connecting roads will be naturally arranged at these intervals.

4. Application to Linear and Dot Shaped Group Residential Quarter.

Since arable land is separated from group residential quarter which forms a line farm roads are the same as those in the case of arable land of concentrative group residential quarter. If the farm roads are arranged orderly like chequers where residences are dotted the roads will hit on them. Because the roads, if curved, will interfere with traffic, the intervals of the branch farm roads are determined adapting to the positions of residences, instead of setting a uniform layout of roads. If possible, remove of residences will be taken into account. Among branch farm roads, the cultivation roads connect the arable land with the residences and the connecting roads link the arable land blocks with each other, but the disorderly layout of residences render it impossible to make the functional distinction between cultivation roads and connecting roads. Therefore, if the connection between residences and arable land is taken into account, closely arranged roads are necessitated and the field block surrounded with roads becomes smaller than that of the concentrated residential quarter. Since the residential layout is not fixed, it cannot help but to form a road plan case by case.

B-2 Shape and Size of Compartment.

> Compartments will be classified into farm block, field block and unit field block, and firstly the type of field block be fixed to plan the layout of blocks.

[Explanation]

(1) Names and Description of Compartments.

Farm block is a unit of management and work control and normally comprises two field blocks. The shape and size of a field block are such that enable proper carrying out of irrigation and drainage control.

The shape and size of a unit field block are such that enable efficient work control by large farm machineries, and generally the field block is an aggregation of unit field blocks.

To explain it more concretely, the farm block is a rectangular block surrounded with farm roads, and is a unit for planning of management, cultivation control and land use for enabling the water and work control to be performed on the same conditions.

The field block is a block with the maximum shape and size which enable to carry out the proper water control in paddy cultivation, being a unit to be determined by such conditions as the soil and groundwater of the district, the irrigation and drainage system of the broader region, the topography and the climate. In general, a farm block is consisted of field blocks locating on both sides of a small drain. Accordingly, the field block is a block surrounded with such permanent facilities as farm roads and irrigation and drainage systems.

The unit field block has the shape and size determined as a working unit of the farm machineries. The unit field blocks are bounded by borders and generally their aggregation is a field block.

(2) Idea for deciding Block Shape.

The idea for deciding the shape and size of a block is that efficient work can be carried out by farm machineries presumed as a condition, that farm work control is capable under mechanization system which can be established as a farm management system in the district concerned in future, and that water use facilities are improved so as to enable proper control of irrigation and drainage of paddy fields to advance the land productivity and the paddy field use.

However, the true state of things is that neither the mechanization system nor the farm management system is concretely established yet.

Thus, since a factor which can be deemed as stabilized in a way in the long term is the irrigation and drainage control, the shape and size of a field block is determined at first taking it into account to form the plan with unit field blocks constituting a variable determinant.

In the case of the model field of Takasu District, Gifu Prefecture, for example, the area of a field block is very great. (125x 600m - 7.5 ha). The mechanization system as the condition of field readjustment assumed the plow cultivation (two-row plow by then (1960) 35 PS tractor and the aerial spraying of insecticide by a helicopter. Also paddy cultivation by direct sowing and use of combine for harvesting were planned (but these have not been realized).

As to the water control, since the district is a low land with high groundwater level and the paddy fields are those reclaimed from raised paddy fields, it was consolidated with its focus laid on the drainage. Underdrainage and surface drainage were divided by blocks, each of which being farm block as a unit to be drained by pump to enable the drainage by blocks and as well to effect a systematic irrigation through pipeline laid under the roads by blocks, using the pump concurrently for the latter purpose; thus mechanization and automatization of water control has been made possible throughout the irrigation and non-irrigation periods.

These measures have provided a sufficient possibility to advance not only paddy production but paddy field utilization.

In this district among farm works under mechanized system which was assumed as a condition at that time, paddy transplanting and harvesting are still performed by hand work. The results of questionnaire made in this respect showed that many replied referred to the blocks being too large for paddy transplanting and harvesting works. Furthermore, the fact that the farm households on large scale management are those being simultaneously in different occupation has arrested the development of management with the resultant diminution in the degree of land use.

B-3 Shape and Size of Field Block.

The shape and size of a field block will be determined within the following limits in reference to longer side a and shorter side b of such block shown in Fig. 8.

1. The length a of longer side is the permissible length of an irrigation ditch, within the limits of 300-500 m.
2. The length of a shorter side is fixed within a range so far as the surface drainage can be smocthly effected, being 100-300 m taking account of the distance from the small drain. Accordingly, the areas of field blocks range from 100x300 m (3 ha) to 150x600 m (9 ha).

[Explanation]

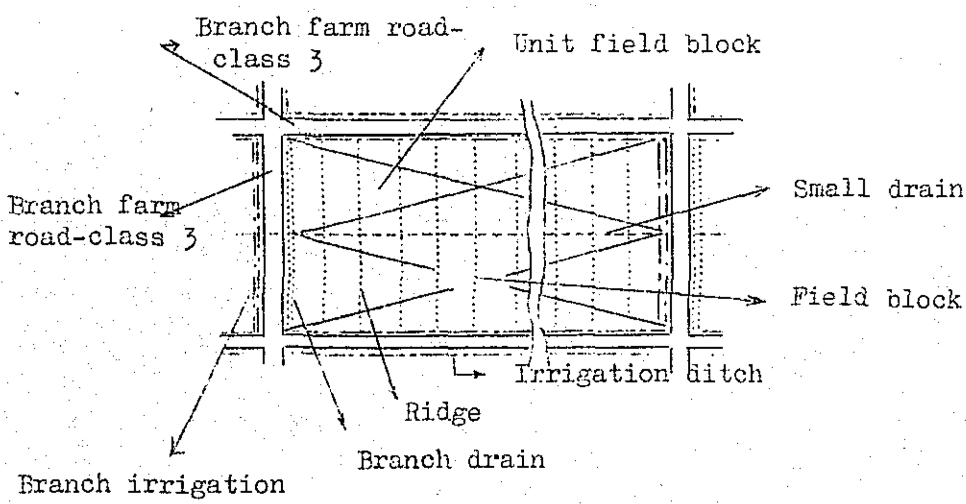
(1) Longer side (a) 300-600 m

As to the determination of the permissible length of an irrigation ditch, see D-2.

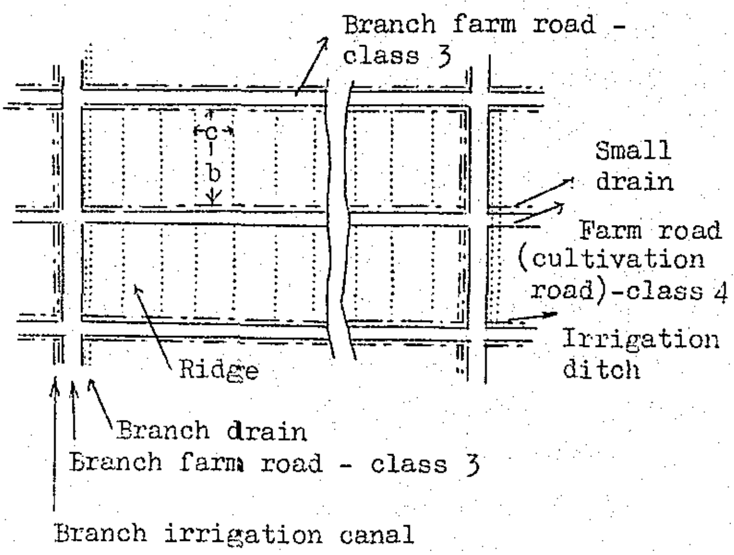
(2) Shorter side (b) 100x150 m

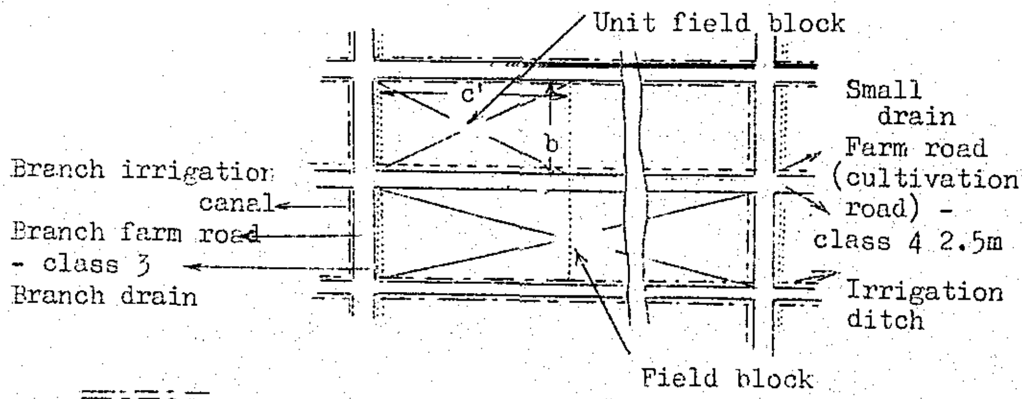
The condition for smooth removing of surface water, based on a certain area, differs according to the distance from the small drain, the soil texture, the groundwater level, the existence of sub-drain and the evenness of surface and it is proper to set the limit at 150 m at first. The selection of a length among 100-150 m is to be made based on the soil texture with 100 m set for clay.
See D-4.

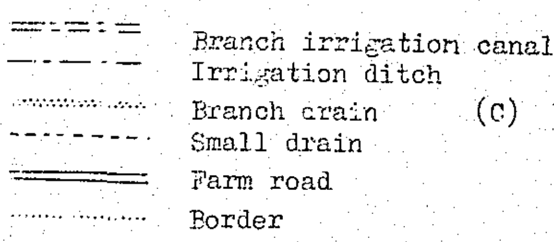
(A) *In the case where border sprayer is used*



(B) In the case where border sprayer and speed duster are concurrently use or border sprayer is used with being more than 100 m.







(C) In the case where speed duster is used.

Fig. 7 Relations of sprayer to farm, field and unit field blocks, farm road and irrigation and drainage channels.

B-4 Shape and Size of Unit Field Block.

> The shape and size of unit field block will be determined within the following limits in reference to longer side b of such block (shorter side of field block) shown in Fig. 7 and shorter side c (Fig. 7-B) or C' (Fig. 7-C).
>
> 1. The length of longer side b is determined as the maximum figure according to the type of insecticide applying machine within the limits of 100-150 m.
> 2. The length of shorter side c is adapted to spraying of liquid agent by a border sprayer, with the standard figure of c at 30 m.
>   In this case, the boundaries between unit field blocks are borders capable to walk on them.
> 3. The length of shorter side c' is adapted to dusting of powder insecticide by a speed duster, with the standard figure of c' set at 300 m.
>   The standard or the maximum area of a unit field block is 30x100m (0.3 ha) for border sprayer and 300x100m (3 ha) for speed duster.
> 4. Where the speed duster is used, Class 4 farm roads are built along the small drains (see C-7).

(Explanation)

(1) Farm Machineries which restrict the Shape and Size of Unit Field Block (see Fig. 7)

As stated in B-2, in contrast to the field block of which shape and size are determined mainly on the consideration of irrigation and drainage control, those of the unit field block are determined chiefly by the suitability of the operation efficiency and control of farm machineries.

Therefore, they may differ in accordance with the conditions which presume the types, sizes, performances and utilization organizations of the farm machineries to be introduced after the completion of the field readjustment. In the present state of things, insecticide applying machines, among large farm machineries, more greatly restrict the shape and size of a block as compared with machineries for plowing, puddling and harvesting, and they may seem to be a factor to determine the upper limits of such shape and size.

The insecticide applying machines include sprayer (for liquid agent) and duster (for powder agent). Since the liquid and powder agents have their proper characteristics which make it difficult to select between them and the type of a unit field block differs greatly in accordance with such selection, the border sprayer and the speed duster are mentioned here as examples.

a. Where only the border sprayers are used.

b. Where only the speed dusters are used.

c. Where both are used in combination.

The following considerations are made on each standard type of the insecticide applying machines.

(2) Where only the border sprayers are used

Since the presumed standard of hose length is 100 m, the longer is 100 m, the longer side b cannot exceed 100 m to a great extent. As the standard of the effective spraying width is 15mx2 presuming to spray the both sides from a border, it is necessary to build such borders at the intervals of 30 m for the farmer to walk on them; thus the shorter side c is determined. Accordingly, the standard area of the unit field block will be 100x30 m (0.3 ha).

Since this size presumes the performance of a border sprayer as its restrictive condition, it is needless to say that such size should vary in accordance with any change in the assumption. The same applies to the following cases of (3) and (4).

(3) Where only the speed dusters are used (Fig. 7 (c))

As the effective range of the presumed speed duster is 100 m in a state of calm and the dusting is possible only from the windward, it needs farm roads capable of the speed duster to pass it to be provided at the intervals of 100 m. Accordingly, it needs to build the farm roads of Class 4 (see C-1) along the small drains as determined in B-3, which constitute the upper limit of b. c' does not need to be restricted if only the speed duster is taken into account. Therefore it may be of the same length as that of the longer side of the field block, and the area of the unit field block will be 100x300 - 600 m (3-6 ha). However, it is safer for the machineries in present use to limit the per day process of puddling work to 3 ha at the maximum, and if this is to be the upper limit of a unit field block, then c' = 300 m putting b = 100 m.

(4) Where both are used in Combination (Fig. 7 (B))

The farm roads of Class 4 are built along the small drains, putting the size of a unit field block at 100x30 m (0.3 ha) with borders being capable for the farmer to walk on them.

(5) Where aerial spraying is performed.

It deems to be fairly difficult in the present situation to protect against insect damage more perfectly only by aerial spraying by a airplane, which is not assumed as a condition. In future, when such protection becomes possible only by aerial spraying and the system of dry field direct sowing is established, making any puddling unnecessary, it will not need to divide the field block into unit field blocks, of which shape and size will be determined by the factor applicable to the field block.

(6) *Managerial Conditions and Unit Field Block.*

Where the products vest in the ownership of joint management, the shape and size of blocks can be determined basing on only the technical conditions. Whereas, in the case where the products belong to the individual management though the principal works are performed jointly, the individual ownership of arable land is bounded by borders which constitute the condition usually to restrict the shape and size of a unit field block under the petty management obtaining in our country. In some cases, the unit field blocks may be enlarged only showing the boundaries by stones or pegs.

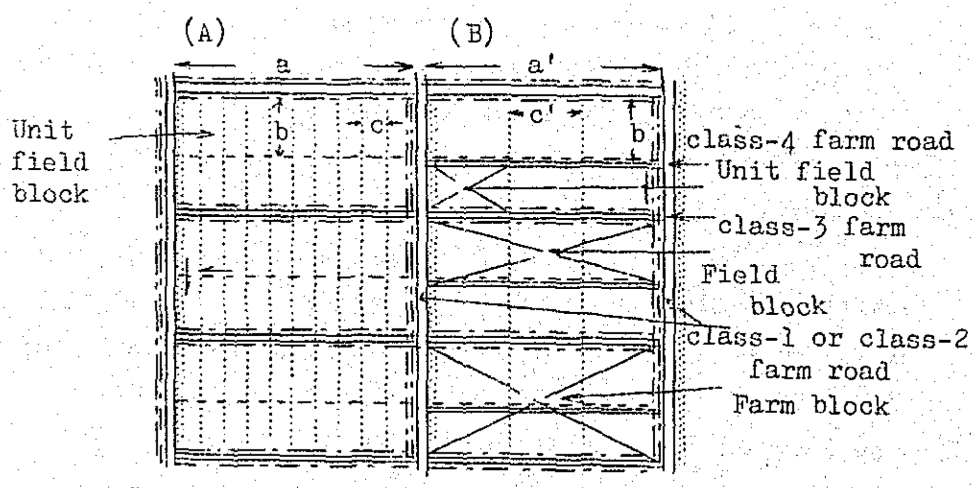


Fig. 8

C. Farm Road

C-1 Width

> The width of a farm road will be the sum of the effective width and the width of both shoulders, putting it at 7 m for Class-1 farm road, 6 m for Class-2, 4 m for Class-3 and 3.0 m for Class-4.

(Explanation)

Farm roads are classified into the following four classes on the basis of width. The width of a farm road is the sum of the effective width and the width of both shoulders.

(a) Class-1 farm road has a width of 7 m. It includes farm village community roads with heavy traffic.

(b) Class-2 farm road has a width of 6 m. It includes farm village community roads and main farm roads.

(c) Class-3 farm road has a width of 4 m. It includes branch farm roads (cultivation and connecting roads) except the following class-4 farm roads.

(d) Class-4 farm road has a width of 3.0 m. It includes branch farm roads (cultivation roads) along the small drains, which are necessitated when the speed duster (powder agent) is used for insecticide applying.

Usually, the width of road is determined taking account of the kinds of vehicles running on it, the frequency of use, the converted land, the construction, maintenance and operation costs and the future prospect of widening, but here the standard is shown based on only the vehicles running on it.

For Class-1 and Class-2 roads, the medial clearance between vehicles is put at 0.5 m and each outer allowance at 0.3 m with about 0.5 m provided for shoulder portion. For Class-3 and Class-4 roads, their widths are determined providing about 0.5 m as shoulder portion. The width of Class-1 road is 7 m to allow the anticipated passing by of tractors (2.4 m in width). Class-3 road locates in the jointly used arable land and the sufficient width of it is 4 m even if a combine runs on it as there will be no passing by. Class-4 road is used only for the speed duster (powder agent), and 3.0 m suffices for its width. The widths of vehicles expected to run on the farm roads are approximately as follows:

Motor car	1.9 m
Truck (5 ton)	2.4 m
Tractor (40 PS class)	2.0 m
Trailer	1.9 m
Combine (3.0 m in havesting width)	3.5 m (in overall width)
Speed duster (tractor-drawn type)	1.9 m

C-2 Height

> The height of road will be 30-50 cm.

(Explanation)

Although the larger height of a road is better from the maintenance standpoint, a proper height is about 30 cm considering the access of machineries to the arable land from the road and the ventilation of air. An extrabanking is carried out on the weak foundation against any anticipated subsidence. The height of Class-1 road is set at 50 cm.

C-3 Transverse Shape Figure.

The slopes will be provided from the road center toward its both sides to improve the drainage of road surface. The angle of slope will be 3-6 % for sand or gravel road and 1.5-2 % for concrete or asphalt paved road. The gradient of banking will be 1 : 0.5 - 1.

[Explanation]

The transverse shape figure of the road needs not be parabolic and it is enough to make the road center higher to some extent. As to the cross-slope, the greater it is the better it is for drainage and vice versa for vehicle running. But the greater cross-slope is better as to farm roads because the vehicles run on them at low speed. The gradient of banking is 1 : 0.5 - 1 in order to reduce any converted land.

C-4 Pavement

The types of pavement include sand type pavement, asphalt and concrete pavement. They will be determined taking the construction cost and the traffic volume into consideration.

[Explanation]

The sand type pavement includes gravel road, crushed stone road and sandy clay road. The pavement cost accounts for a large part of the road construction cost. The price of gravel of which purchase and transportation costs account for the prinpal part of it varies greatly by districts. Any saving in the road cost may be effected by reducing the amount of gravel use or by carrying out appropriate maintenance and administration of sand road. The usual depth of gravel layer is 10-15 cm, which is determined properly, judging the strength of soil and the muddiness. It is an effective way to spread the gravel in several times over some years, because too much gravel covering the road makes the vehicles difficult to run on it.

C-5 Intersection

> The intersections of roads will be provided with corner cut-offs to widen them. However, this is not needed for the intersections of Class-1 or Class-2 roads. The corner cut-offs with 1.5 m of one side will be provided only at the intersections of Class 3 or Class 4 roads.

(Explanation)

The corner cut-offs are restricted to the minimum of necessity since they break the orderly shapes of the unit field blocks and the farmers dislike to have them. Taking account of the widths of tractors drawing trailers and of combines, the corner cut-offs with 1.5 m of one side are provided only at the intersections where Class-3 roads and Class-4 roads cross with each other.

C-6 Access Road.

> One or two access roads will be built at each unit field block, with hume pipes laid in the small drains alongside of the farm roads or V-type flume pipes covered with concrete plates so that any machinery can

make free access to the arable land. The width of the access road will be 4 m, with a gradient less than 18°.

(Explanation)

An access road must be built so that any machinery can make free access to the field even if the difference of levels between it and the farm road is 30 cm, because an irrigation ditch is usually located alongside of the latter. An unit field block of 50 ha or less is provided with one access road at its left end as faced to it from the farm road. This is because the combine operates very often by turning round clockwise. An unit field block of 50 ha or more is provided with two access roads at the left and right ends as faced to it from the farm road. The width of the access road is put at 4 m, taking account of the turning radius of the tractor and the use of the combine. Where the level difference is less than 30 cm the access road is formed with hume pipes covered with earth. As the limit of hill-climbing ability of a tractor is 18°, the gradient of the access road should be less than 18°.

C-7 Road Bridge

The width of a road bridge on Class-3 or Class-4 farm road will be the same as that of the road. Its railings will be as low as possible.

(Explanation)

As stated above, since the widths of the farm roads are precisely defined, the width of a bridge on Class-3 or Class-4 road is the same as that of the road. If the width is compelled to reduce, the corner cut-offs are built at the approaches of the bridge. The shoulders of a bridge on Class-1 or Class-2 farm road is about 0.25 m. If the length of a bridge is less than 10 m, the width of the bridge is the same as that of the road. The height of railings is lowered so far as any wheel will not run over them, taking account of the loads on vehicles and the width of work machineries.

D. Irrigation and Drainage Facilities.

D-1 Water Requirements.

(1) It is assumed as a condition that the supply of the total amount of water required during an irrigation period and that of the water requirements by seasons will be secured adequately.

(2) The standard average water depth on every parcel of paddy field will be 20-30 mm/day.

[Explanation]

The types of irrigation and drainage facilities described in the following can only be dealt with based on the assumed condition that the sufficient amount of required water is secured, in order to effect the proper water control by parcels of paddy field in harmony with the growth stages of paddy, the climatic conditions and each cultivating work.

The paddy fields having the water requirement in depth of 20-30 mm/day are deemed not only proper for the paddy growth but desirable for both of their surface drainage and underdrainage. Therefore, with the proper water requirement of 2C-3- mm/day set as future standard, it needs to improve the irrigation - drainage and the soil layer conditions so as to enable to control the amount of percolation as well in harmony with the growth stages and the climatic conditions.

D-2 Irrigation Canal

(1) The type of water channel will be open channel or pipeline. In case of the open channel, the branch canals will be lined as a rule, and the ditches will be earth or lined canals or flumes. (2) The cross section of the channel will be such which can bring water at peak water requirement and the head allowance be one third of the maximum water flow. (3) The length of irrigation ditches will be 300-600 m with the same cross section at both the upstream and downstream.

[Explanation]

(1) Advantages of Open Channel and Pipeline.

So far, the general practice has been to build the branch irrigation canals and irrigation ditches of the paddy fields as open channels. In future, there will be some cases where the pipeline is more advantageous as the irrigation system of the paddy field in view of the convenient maintenance and operation, the improved pipe materials, the convenient access of machineries to the unit field blocks and the demand for reducing converted land.

The pipeline is more advantageous than the open channel where the following conditions exist.

(1) Where the water pressure can be increased by pumping

up from the water source.

(2) Where the cross section of the open channel becomes sub-stantially large because of the small gradient of the channel due to flat terrain.

(3) Where the local demand is great for reducing the converted land to road and water channel.

(4) Where the reduce in conveyance and distribution loss of water is particularly desired because of the deficient water.

(5) Where there are particular demands for the savings in the labor for maintaining and operating water channels and for controlling water.

(6) Where the ground is well stabilized, without any fear of ununiform subsidence.

(7) Where there is not any remarkable difference in construction cost between the open lined channel and the pipeline.

If the above conditions are satisfied, the comparative design of the pipeline system against the open channel is prepared to determine the adoption of that system.

Although there are many cases, in general, where the pipeline system is more advantageous on the flat land from the functional point of view, the greatest problem here is the compatibility of its utility with its construction cost.

In this, at Takasu Wanaka District, the pipeline system has been adopted, with its utility confirmed, and the local farmers requested to convert the earth canal built for comparison purpose to pipeline.

(2) Necessity for Lining of Open Channel.

Where the irrigation ditch is built as an open water channel, the necessity for its lining (including flume) is decided basing on the consideration of the following points.

1. Where the leakage loss exceed 100 % due to the great permeability of soil layer (above $K = 10^{-4}$ cm/sec.)
2. Where the ground foundation or the earth of water channel is liable to scouring and decaying, with resultant difficulty in the maintenance and operation.
3. Where the greater cross section is needed because of the small gradient of the water channel due to the flat land.
4. Where the ground is well stabilized, without any fear of uneven subsidence.

If the above conditions are satisfied, the comparative design of the open channel against the earth canal is prepared to decide the necessity of lining.

Where the branch canal is built on the flat land, it is a rule to reduce the cross section by decreasing the coefficient of roughness and to perform lining taking account of the convenience for maintenance and operation.

(3) Cross Section of Irrigation Canal.

The cross section of an irrigation ditch is determined based on the maximum water flow, decided according to the water distribution plan prepared with referring to the standards shown below, after the examinations of the length of optimum paddy cultivation period and the operational efficiencies of various machineries at the time of the peak water requirement abovementioned (at the time of puddling, initial water application to direct sowing dry field and germination of direct sowing flooded field, immediately after "nakaboshi" drainage, and at the time of weeding, insecticide applying and manuring).

1. That the water application to each unit field block is

completed in the day.

2. That the water application to respective field block (300-500 ha) is completed within ten days.
3. That the water application in the district is completed within ten days.

The water supply at the times of above peak water requirements and the routine supply must make it a rule to carry out on the 24-hours per day irrigation basis (excluding the pump irrigation), otherwise the water cross section will become excessively large. Therefore, where it is needed to make a concentrated irrigation during short hours in a day, some measures must be taken to regulate the water utilization.

The desirable free-board of an irrigation canal is one third of the maximum water flow.

The water cross section of a pipeline is calculated from the correlation to the above peak water flow and the increased pressure, and the equivalent of the free-board is added in calculating the increased pressure.

(4) Difference in Levels of Irrigation Canal and Field Surface.

If the level of the irrigation canal-bed is higher than that of the paddy field surface in excess, it will not only interfere with the access of machineries into the arable land, but necessitate to provide special device at the water inlet to prevent the land from scouring. If the canal-bed level is lower in excess, the water intake to the unit field block will be difficult. Thus, it is desirable that the canal-bed level is within the range of (-)5 - (+)10 cm against the field surface.

The height of a water channel bank should be limited to the same level as that of the road surface, at the most.

(5) *Length of Irrigation Ditch.*

If the area irrigated by the ditch diverging from a branch irrigation canal is excessively broad and the number of unit field blocks to which water is distributed increases, the length of such ditch will be liable to cause the conflict of interests between its upstream and downstream areas in regard to the equal distribution of water, and a water deficiency be apt to arise in its downstream area if a special regulation of water utilization is not made.

The ditch must bring large amount of water to the unit field blocks at its most downstream in puddling period and the like; or, if any water intake is suddenly suspended at its upperstream area during the routine water application time, there is a fear that excess amount of water will reach its downstream area; and it is a rule that any one ditch have the same water cross sections at its upstream and downstream.

Therefore, it is not desirable that the length of one ditch is excessively long, from the standpoint of the water control as well as the construction cost. On the other hand, an excessively short ditch causes the high density of Class-3 roads along the branch irrigation canals, with the converted land increasing.

The experience of the district readjusted under the former system of 30 a blocks (30x 100m) shows that the long ditch covering more than 20 parcels on its one side (the length of ditch being 30x20=600m often causes inconvenience for equal distribution of water and that the branch canals should be built at the intervals of 300-600m.

D-3 Water Inlet.

(1) The layout of water inlets: one or more inlets will be built at the side along the irrigation ditch of each unit field block, at the intervals of 50 m or less, and if the inlet is one for a block it will be provided at the upstream part on such side. (2) The cross section of the inlet from an open channel will be determined according to the amount of intake water, with the upper limit of the width being less than 50 cm, or two inlets will be built where the larger width is needed. The level of the inlet bed will be set at 0-10 cm above the field surface. (3) It will be built as a fixed construction convenient for manipulating its opening; or the valve system will be applied to the pipeline.

[Explanation]

(1) Number of Water Inlets and their Layout.

The number of water inlets necessary to bring water from the irrigation ditch onto the individual unit field block is determined by the area of the unit field block, the maximum intake water flow to be decided basing on the time required for the water application and the length of the side along the ditch of such block.

For example, if 200 mm of water required for puddling (usual requirement is 120-180 mm) is applied to 1.0 ha in 24 hours, the necessary water flow will be 23.1 l/sec which shows that one inlet will suffice generally for up to 1.0 ha, seeing from the possible intake water flow of one inlet (as mentioned below).

Where the ditch is arranged along the longer side of the unit field block, it is desired to provide two or more inlets at the intervals of 50 m or less even if the required intake water flow is small, in order to expedite the water circulation in the block at the time of water application.

It is advantageous to locate the inlet at the upstream part of the side which gives the largest head between the water level of ditch and the field surface.

(2) Cross Section of Water Inlet.

The allowable velocity of flow in the vicinity of the water inlet is deemed about 40 cm/sec (critical to lodging of paddy plants and scouring of field surface), so if the head between the water level of ditch and the field surface and this allowable velocity of flow are given, the width of inlet will be determined.

As the excessively wide inlet is inconvenient for its opening manipulation the maximum width is limited within 50 cm. If the required intake water flow needs a larger width than this, two or more inlets are to be built.

The level of the inlet bed is dependent on the level of the ditch bed, but it is desirable to be within the range of 0-10 cm above the field surface, in view of the prevention from scouring at the time of inflow.

(3) Structure of Inlet.

Where the unit field block is larger, the intake water flow becomes larger as well, so that a mere notch cut in the ditch bank cannot be easily maintained and operated. Therefore, the inlet should be a fixed structure of concrete with corner cut-off or of sluice type.

Where the irrigation ditch is the pipeline the valve system is applied.

D-4 Field Surface Drainage.

> It is necessary that the field surface drainage of each field block can be completed within one day after the drainage is started, and things must be conditioned so that this can be attained.

[Explanation]

(1) Necessity of Field Surface Drainage.

Since the flatness of a paddy field surface deteriorates with the expansion of a compartment, the expedited drainage of the ponded water on field surface becomes more difficult than the former smaller compartment. On the other hand, the expedited drainage is needed more keenly because of the strengthening of land resistance for running of large machineries and the introduction of new cultivating method.

Thus, the field surface drainage is the most important prerequisite for the mechanization by large machineries, and the various facilities (flatness of field surface, soil improvement, underdrainage, training drain and outlet) must be improved so that such prerequisite is satisfied.

(2) Allowable No. of Days for Field Surface Drainage.

Summarizing the data of experiments and the experiences in the past, it may be said the standard number of days allowable for draining the ponded water on the paddy field at respective times in the year is generally as follows.

1. Irrigation period:

Time of applying weed killer and liquid manure ..... within 1-2 days

Germinating time of directly sowed flooded field	within 1 day
Time of "Nakaboshi" drainage	" 2-3 days
Terminating time of irrigation ...	" 3-5 days
Drainage of water ponded (excess of 10 cm in depth) due to heavy rain	" 1-2 days

2. Non irrigation time (drainage of ponded rainwater):

Period of tillage and stamping work	within 1-3 days
Seeding period of direct sowing dryfield	" 1-2 days
Germinating period of directly sowed dry field	" 1-2 days
Harvesting period	" 1-2 days
Cultivation period of second crop	" 2-3 days
Autumn plowing period	" 3-5 days

Therefore, it is desirable for the paddy field to statisfy the condition of the field surface drainage that the ponded water on the field surface can be drained within one day.

(3) Paddy Field with Poor Quality of Surface Drainage.

In general, the paddy fields on which ponded surface water cannot be drained completely within one day are those shown in the following.

1. Paddy field of which longer side of the compartment (or the distance to a small drain) is more than 100 m.

    Seeing from the investigations and experiences in various regions, where the permeability of the soil is poor the ponded water is often remaining at places 100-150 m away from the outlet still after more than one day even if the flatness of the field is good, and the standing water is apt to remain particularly in depressions.

2. Paddy field with poor flatness of its surface.

Where the flatness of the field surface is poor, even if the longer side is less than 100 m, the standing water remains everywhere, and it cannot be drained from the outlet as surface water.

3. Paddy field of which soil layer has poor permeability.

Where the paddy field of which subsoil has poor permeability, the ponded water on the field surface must be entirely drained from the outlet as surface water, and the remained water stands still for several days.

(4) Measures for Field Surface Drainage.

In order to effect the quick drainage of field surface it needs to improve the flatness of the surface, the soil layer, the underdrainage and the outlet and to build the field surface drains. The drains are built in the lateral direction to the drainage channel (or generally in the direction of the longer side), at the intervals of 10-20 m, with their terminals connecting to the outlets, and it is effective to connect to the depressions liable to retain standing water with branches on occasion.

The better construction method of field drains where the direct sowing dry field is concerned is to dig them by plow at around the seeding period, and for puddling, to dig them between ridges by hand at the time of "nakaboshi" drainage.

D-5 Outlet

(1) The layout of outlets: one or more outlets will be built at the side along the small drain of each unit field block, at the intervals of less than 50 m, and if one inlet is provided for the block it will be built at the downstream part of such side.

(2) The cross section of the outlet will be less than 50 cm in its width, or two outlets will be built where the larger width is needed. The level of the outlet bed will be set at 5-10 cm below the field surface.

(3) It will be built as a fixed structure convenient for manipulating its opening, with its small drain side be of drop type.

(Explanation)

(1) Number of outlets and their layout.

The outlets necessary to remove the ponded water on the field surface of individual unit field block into the small drain should be built at the rate of one for every 50 m or less, taking account of the flow out from the field surface drains, though one outlet for every 1 ha may serve where the depth of water is still great.

If one outlet is built for a block it is advantageous to provide it on the lower part of the side, in view of the head between it and the water level of small drain and of the connection to the training drain along the borders.

(2) Cross Section of Outlet.

The inner width of the outlet is limited within 50 cm for the convenience to manipulate its openings, and if the width more than 50 cm is needed by the required drainage discharge two outlets should be built.

It is advantageous to set the level of the outlet bed at 5-10 cm below the field surface, both for increasing the discharge at the initial period of drainage process and for connecting to the field surface drain.

D-6 Drain

(1) The type of the drainage channel will be of open channel.

(2) The cross section of the drain will be of two types depending on the groundwater level.

1. Where the groundwater level is low at all times -
   The cross section will be such that the maximum drainage discharge of surface water can flow through it, with the depth limited to 50-60 cm below the field surface

2. Where the groundwater level is high -
   The small drains will be made as deep as 1 m below the field surface, taking account of the underground drainage.

(3) The structure of the drain will be of the open channel type, as a rule, and the bank revetment work will be per formed if necessary. The check dams will be built in the small drains by field blocks or by heads of 50 cm in accordance with the topographic gradient.

(4) The upper limit of the length of a small drain is 600 m.

[Explanation]

(1) Function and Cross Section of Drain.

Where the paddy fields are such that their subsoil water level of the non-irrigation period is several meters below the field surface and, even in the irrigation period, the ponded water on their surfaces and the subsoil water do not saturate and connect with, making free seepage (fields on a tableland or the upstream part of an alluvial cone) the drains of small depth with the function only to discharge the surface water will suffice for such fields. In this case, the cross section, being the optimum one in view of the topographic gradient and the amount of earthwork, is determined basing on the planned drainage discharge estimated from the run off ratio computed taking account of the rainwater storage on the field surface. It is an usual practice to limit their depth within 50-60 cm below the field surface.

Where the paddy fields are such that their subsoil water level of the non-irrigation period is as high as 1 m or less below the field surfaces, or such level raises in the irrigation period or the subsoil water and the ponded water on the field surface become saturated and connect with even though it is low in the non-irrigation period (usual flat paddy fields), the drain must function in two ways; the surface drainage and the subsurface drainage functions. Therefore, the cross section of the drains for these fields should have the capacity to flow the water discharged from the surface and at the same time the depth of about 1 m below the field surface necessary for the sub-drainage.

However, where the sub-drainage is separated from the surface drainage by means of the underdrainage (collecting galleries) and the subsoil water is trained far to out of the district, the drains which discharge only the surface water may well suffice for the latter fields abovementioned. In general, as it is difficult to provide the necessary gradient for collecting water in the gallery on the flat land and the connecting portion of absorbing and collecting galleries is liable to damage, it is desirable to have each absorbing gallery is opened toward the small drain. Therefore, the small drains are needed to have the depth of about 1 m below the field surface.

(2) Structure of Drainage Canal

As a rule, the drains are constructed as earth channels in order to save the construction costs. But the deep drains in respect of which the subsurface drainage function is taken account of, the bank revetment is needed in the following cases.

1. Where the soil of the slope has a property liable to break.
2. Where the ground foundation is weak and apt to subside.
3. Where the soil is liable to be eroded due to the high velocity of flow.
4. Where the water level varies very frequently due to the control of the channel water level.

Where the bank revetment is practiced, the revetted surface should be of transmissive structure, with emphasis laid on the subsurface drainage function.

(3) Water Level Control of Drain.

In order to control the amount of percolation in accordance with the growth stages of paddy by controlling the water level of the drains and to regulate the subsurface drainage on one field block basis, it is necessary to build a check dam at the small drain terminal of each field block or at every hald-way of the field block where the head varies by 50 cm, so that the subsurface drainage can be controlled at will in harmony with the growth of paddy and the management of farm works and cultivation.

(4) Length of Small Drain.

If the length of any small drain extending to join to the branch drain is excessively long, the cross section of downstream part is enlarged with increased construction cost, and it is apt to cause the confliction of interests between the upstream and downstream areas. Since such disadvantages are prominent where the small drain exceed 600 m (20 blocks of respectively 30 a), it is desirable to build branch drains at the intervals of 600 m or less laterally to the small drains to be connected to them.

D-7 Block System Drainage

(1) In some cases, it needs to consider the adoption of a block system drainage for the purpose of the vertical control of water and the repeated use of water.

(2) The size of a unit block deemed to be suitable in respect of the drainage control is generally 30-50 ha.

(3) The necessary facility is a small pump to be installed at every unit block.

(Explanation)

(1) Necessity of Block System Drainage.

In order to enable the vertical control of water taking account of the behavior of water in the soil layer at about 1 m below the field surface, with the purpose of strengthening the bearing capacity and of proper percolation, the water level of drains in the field must be kept deep at need. This in turn necessitate to make deeper the branch and main drains in the district, with the resultant need for pump drainage instead of the usual natural drainage, or with the existing pump drainage necessitated to increase the lift head. The necessity to lower the water level of the terminal drains calls for excessive remodelling of drainage system and facilities in the whole of district. A measure to cater for this situation is the block system drainage by the use of small pumps. The method of construction is determined taking into due consideration the construction cost, the maintenance and operating cost, the convenience for water control and the repeated use of water.

There is a tendency that the water requirements increase with the modernization of paddy cultivation and the readjustment of fields. Furthermore, where it is difficult to find a new water source to meet those requirements, the necessity to make the repeated use of water systematically increases its importance. The flat land makes it difficult to practice the repeated use of water by such means as the special irrigation and drainage system or the backwater device, and this too necessitate the drainage by block system which takes account of the repeated use of water.

It is the maintenance and operating cost of pumps which so far has arrested the diffusion of the block system drainage by a small pump. However, in the advanced paddy cultivation zones such as Niigata, Nobi and Saga plains, the block system drainage has been partially practice with some effectiveness. It is believed to be an essential drainage system in future for improving the field conditions capable to adapt to the mechanization by large machineries and the high yielding of crop.

(2) Area of Unit Block.

The area of unit block for the block system drainage varies according to the topographical conditions, the irrigation and canal system and the bearing capacity for the maintenance and operating cost of pump. The experiments and experiences at various districts has shown that the suitable area is 30-50 ha, in view of the easiness to perform the regulation of water level throughout all fields and of the maintenance and operating cost. A pump with a small lift head and of 1 HP/ha in output is suffice for the flat land, as well the unit block of 30~50 ha does not necessitate so large pump. Such pump can be regarded as a part of work machineries, just like the large machineries used jointly.

D-8 Underdrainage

D-8-1 Planning of underdrainage

The planning of an underdrainage will be determined in the order of the depth, the intervals and the gradient, and the layout of the absorbing pipes is as per Fig. 9. The sub-drains are buried in the soil layer with good permeability as deep as possible, but within a range of 0.6 - 1.25 m, taking account of the surface drains, at intervals to be decided by depths and permeabilities of soil.

〔Explanation〕

Since the improvement of the permeability of soil layer and the strengthening of the bearing capacity of field are the principal objectives of the underdrainage and they constitute the important conditions of planning of this underdrainage, the following descriptions are made referring to the paragraphs dealing with the soil layer. Also it has close relations to the subsoil water level and the flatness of field.

The depth of sub-drains is usually determined prior to the decision of their intervals, and influenced by the depth and water level of the small drains; it is found empirically on the difference in the soil property and the density of planting. That is, they are buried in the soil layer with good permeability as deep as possible, but within a range of 0.6 - 1.25 m, so far as the depth of the small drains permit it. In particular, as the crack is the principal factor of seepage for the clayish soil, it needs to ascertain the carry-over depth of cracks.

In the case of Takasu district, the shallower subdrains (0.9 - 1.2 m) has resulted to obtain more drainage discharge (see the Report on Investigations of Model Paddy Field, 1966). The major reasons for this are that the district being the creek paddy field befor the readjustment, its soil layer is not uniform horizontally with some portion reclaimed by filling sandy loan, and that the carry-over depth of crack is less than 1 m.

There is a problem in selecting the site, as generally the permeability before the construction work is at the lowest point and increases annually after the construction. Thus, the site should be determined in the light of the prospect at least for one year after the construction, referring to the data of adjacent and the similar land. The average permeability of soil calculated backward from the variations in the water level of arains and the daily recession of water depth, for about 18 ha of field in Takasu district, showed the following results;

$k = 3.9 \times 10^{-4}$cm/sec ..... 2 years after construction (1964)

$k = 5.0 \times 10^{-4}$cm/sec ..... 3 years after construction (1965)

In peaty land, as the ground foundation subsides with the progress of drainage, the depth of the sub-drains should be rather deep, at 1-1.2 m. According to the experiments of drainage technique conducted at Sarobetsu sistrict of Hokkaido (see Jour. JSIDRE, Vol. 35, No. 11), the land surface subsided by 0.5 m in 5 years after the readjustment of the land with the sub-drains buried at the depth of 0.6 m, and the depth of the sub-drains was 70-80 %, although these figures may vary with the properties of peat. Therefore, they should be buried deeper by 20-30 % than the planned depth. The following table shows an example of how to decide the spacing of sub-drains from their depth and the permeability of soil.

Coefficient of permeability (cm/s)	Depth of sub-drain (m)		
	0.9	1.2	1.5
$0 - 3.5 \times 10^{-5}$	0 - 4.5m	0 - 6 m	0 - 7.5m
$3.5 \times 10^{-5} - 1.4 \times 10^{-4}$	4.5 - 9.5	6 - 12	7.5 - 15
$1.4 \times 10^{-4} - 5.6 \times 10^{-4}$	9.0 -18.0	12 - 24	15 - 30
$5.6 \times 10^{-4} - 1.7 \times 10^{-3}$	18 -33	24 - 43	30 - 54

The above table culculated by Slater (1) determines the figures of intervals for each depth higher than those calculated by Schroader, to take into consideration the time needed to lower the groundwater level to a certain depth. It is believed those figures are suitable for the planning of underdrainage to introduce machineries into the fields.

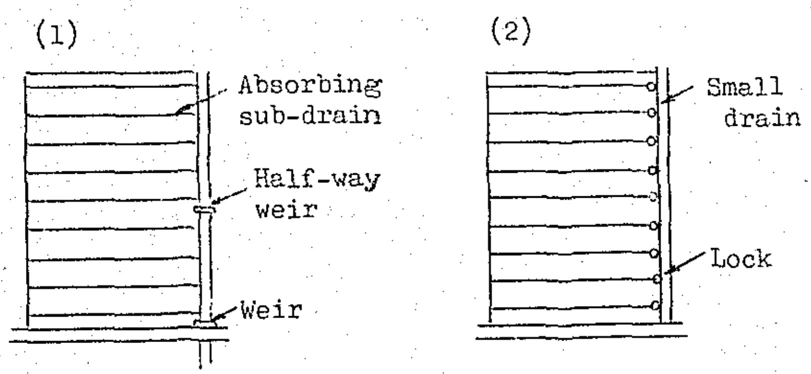
(1) Slater, C.S. : *The depth and spacing of tile drains*, Agic. Eng. 31, 1950.

In using the above table, the coefficient of permeability at the place must be measured, presupposing the soil behavior after the construction of the sub-drain, as in seen from the experience in Takasu District. It is dangerous to plan the underdrainage on the basis of the coefficient of permeability obtained under the water use condition inconceivable at the place, through the indoor experimentation. If the required time for lowering the groundwater level at the center of the sub-drains to 50 cm below the ground surface, all over the district, is put at 5 days basing on the deta of Takasu District, the depth of sub-drain is 1 m with spacing of 14 m, being in the range of Slater's figures.

In the case of clayish soil, it is necessary to start the construction of sub-drain after the permeability of the soil has been increased by the development of cracks. For this, it needs to build a tentative drains, or to lay mole drains at the small depth of 0.3 - 0.5 m, to expedite the drying of the arable land surface. At the reclamation land of Kojima Bay, Okayama Prefecture, the mole drains were layed to increase the permeability of soil, after which the real sub-drains (clay pipes) was buried, with successful results. In this, the real sub-drains were built by the combined mole-pipe drain system, that is the clay pipes were buried more deeper position than and in the lateral direction to the mole drains, connecting the both through the cinder layer. It is an effective method in a district where the mole drain can be built.

The layout of absorbing pipes for the underdrainage is as shown in Fig. 9-(1), and the pipes are opened toward the small drain one by one to connect to it, with any locks omitted. In this case, the weirs provided in the small drain serve as lacks.

Where the depth of sub-drain does not match favorably with that of small drain, the desirable arrangement is to separate the underdrainage from the surface drainage and connect them to the downstream or branch drain through the collecting galleries. In this the locks are built sometimes (Fig. 9-(2)). Also there is a method to connect several absorbing pipes to the collecting gallery at the terminal of which is provided with a lock to connect it to the small drain (Fig. 9 (3) and (4)), but in view of their operation and breakdown of lock, the layout shown in Fig. 9-(1) is more desirable.



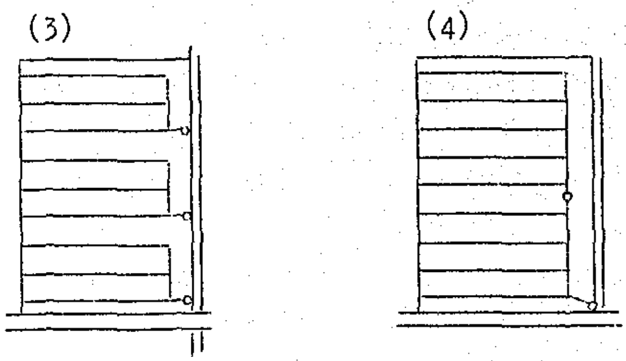


Fig. 9 Layout of Underdrainage

D-8-2 Materials of Sub-drain

> The materials of sub-drain pipes are earthenware pipes, clay pipes and plastic pipes. In back filling, care will be taken not to deteriorate the permeability of the excavated soil layer.

[Explanation]

(1) The earthenware pipes used as a material of sub-drain are those of JIS R 1201-1202, or the unglazed clay pipes corresponding to them, and vinyl fiber pipes. The vinyl chloride pipes should be of quality corresponding to thin skin JIS K 671 and not be reclaimed one.

In order to secure the initial effect of the underdrainage in full, it needs to wind round the pipes with coarse fiber such as straw or brushwood at the rate of one and half bundles (a bundle of 1 m in length and 0.4 m in circumference) or more per unit length of pipe, or for the clay pipes, round the socket portion with 0.2 bundle (a bundle of 1 m in length and 0.9 m in circumference) or more of fresh pine leaves.

Where the plastic pipes such as vinyl chloride pipes are used it is suffice for them to wind round with only the straw. But as they are made of light material it is important to place the protective material of coarse fiber on their upside and both side and not beneath them. The necessary amount of chemical fiber to wind round the vinyl chloride pipes is 40 g or more per 1 m^2 of pipe surface and that of glass fiber is 80 g or more of 16 micron in size.

(2) Since the permeability of the excavated soil layer is liable to deteriorate by machine excavation, it should be avoided as far as possible to fill back immediately after the execution. Instead, the pipes are to be pressed with a small amount of dry surface soil so that they are stabilized, and several days thereafter the back filling is executed with the excavated earth sufficiently air dried. In particular where the soil is heavy clay it is important, in view of the drainage function, that the excavated part is permeable to water, for which care must be taken.

As the materials of sub-drain are generally dropped into the channel bottom, they should be laid so as not any pipe will be broken or the uniformity of the protective materials be decreased. In back filling, care should be taken of not to break pipes with clod or stones.

In the machine execution, it should be cautions not to position the sub-drain outlet opening toward the small drain in inverse gradient, or to replace any defective material with good one. As the materials of sub-drain are tended to be pushed out with the progression of the machine, they should be pushed in at all times during the laying of them; otherwise the connecting portions will get out of place, causing imperfect joint, and the earth and sand come into the pipes will deteriorate their drainage functions.

E. Soil Layer

E-1 Depth of Soil Layer and Content of Gravel

> It is desirable that the depth of surface soil is 15 cm or more and the effective depth of soil layer including the surface soil is 30 cm or more. Also, the surface soil of which gravel content is less than 20% (in volume) must be more than 15 cm in depth.

(Explanation)

(1) Definition

The surface soil means the soil which is turned and stirred in performing the plowing and puddling. The effective soil layer means the soil within the range of which layer the paddy roots can extend and develop with sufficient vitality.

(2) Basis

The depth and property of the soil layer have a unseparably close relation with the soil fertility, and in the first crop after the field readjustment the decrease in the trop yields is caused usually due to considerable irregularity in the growth of plants. Therefore, where the target of the crop yields is set at those before the field readjustment or the higher yields, a special care must be taken of the depth and property of the soil layer. The field readjustment must enable large machineries to operate on the fields, and this also requires to pay a regard to the soil layer. Therefore, there are many cases where a positive improvement of the soil layer is needed. Gravel layer or hard ground impedes the extension of plant roots. The existence of gley layer constitutes an impediment for root system, where the depth of the effective soil layer is less than 30 cm, improvement of the soil layer must be planned in order to remove the factors impeding paddy growth, where the surface soil contains more than 20% of gravels, mechanical impediment will be caused in the management of cultivation, usually resulting in more troublesome operation from the view-point of the cultivation technique.

The surface soil must have the bearing capacity which will not cause any obstruction to the operation of combine in harvesting period..

(3) Method of Investigation into Present status

If it is found that the gravel content of the soil is not very great (or not more than 20%) by the ordinary sampling test, it may be used as surface soil. The content of gravel is found by measuring the weight of content in excavated soil and shown as % in volume of gravels not weathered. In this the amount of gravels found as % in weight is converted into % in volume by the following formula:

$$P = \frac{g.\ b}{g.b + a\ (100-g)} \times 100$$

p - % of gravel in volume

g - % of gravel in weight

a - specific gravity of gravel

b - tentative specific gravity of soil in the place

(4) Methods to improve soil layer

There are several method for improving the soil layer as shown in the following.

(a) Improvement of soil layer by manuring operation

Where there is a fear that the soil fertility not homogeneous between the cut and filled portions influences the growth of crop because the treatment of top soil is not performed, the homogeneity of growing soil layer is seeked for through improvement of manuring and devising of plowing rork. The cut earth portion needs a large amount of manuring, because the influence of deficiency in nitrogen is strong with the absorption coefficient of phosphoric acid increased. The filled earth portion has a tendency to yield too much crop, as a result of excessive amount of nitrogen where the subsoil is converted into the surface soil due to the readjustment earth works, it often causes impediment to the growth of paddy, thus necessitating for manuring control; such impediment may not be removed in one or two years. Although the measures in these cases vary with the kinds of soil, it is usual to practice the increased application of heap and farm manure (2t per 10a), application of siliceous calcium (300 kg per 10a) and the increase in the amount of ordinary fertilizers (by 5-10%). For volcanic ash soil, it is effective to apply large quantity of phosphatic fertilizer. Where there is red withering which sometimes develops on the surface soil converted from the subsoil, it is necessary to prevent extraordinary reduction by "nakaboshi" drainage, avoiding excessive application of immatured barn manure. If the impediment against the growth of paddy is of more than mean magnitude, it needs to practice the improvement of the soil.

Where the subsoil is of inferior soil texture, the depth of plowing is to be increased year by year instead of deep plowing at a time.

(b) Top Soil Treatment

It is disirable not to perform the top soil treatment as far as possible, in view of lightening the farmers' burdens. Therefore, detailed examinations must be made for the following three cases;

(i) Where the top soil treatment is not needed

(ii) Where it is needed

(iii) Where it is difficult to perform the top soil treatment

(i) The top soil treatment is not needed

Where the subsoil is of nearly the same property as that of the surface soil, with the effective deapth of 30 cm or more, and can be converted into the mold by fertilization control; or, where the soil fertility is promoted by mixing the top soil with the subsoil due to the low fertility of the surface soil; or where the more than one third of the depth of the surface soil is not cut and filled.

(ii) The top soil treatment is needed

Where the effective depth of soil is small and the subsoil, being excessively deficient in gravel materials and organic matters, is extremely different from the surface soil so that it cannot be converted into the same soil as the surface soil even by fertilization control; where, in particular, the subsoil includes a hard gravel layer which impedes the spread of paddy roots; where the permeability of subsoil is extremely different from that of surface soil; where the fertility of surface soil is very high, resulting in an economical cost of the surface soil treatment; and where only some small parts (less than 30% of the total) do not need the surface soil treatment.

(iii) The tcp soil treatment is difficult

Where the effective depth of soil is less than 30 cm and it needs to bring earth to peace all over the readjusted area; where the readjustment work is executed on the weak ground or the water-logging paddy field in poor drainage condition.

(c) Evenness of subsoil ----- Reference is made to the standard of evenness for the subsoil.

(d) Evenness of field surface ----- Reference is made to the standard of evenness for the field surface.

(e) Brought earth from another place ----- Earth is brought from another place to improve the mold bed or the surface soil or the both cf them. The effect of the soil brought from another place for the purpose of improving the physical nature of soil (mainly the permeability) appears quickly. The effect to improve the soil fertilization appears gradually. Although it is desirable to mix the brought soil throughly with the ordinary surface soil, except where the ground is being raised, the brought earth, where it is peaced on the peat, is mixed little by little with the decomposition of peat, instead of mixing them at once.

The silt of the river, lake or pond is used as the brought earth for the purpose of replenishing the organic matters. In this, it is necessary to dry the matters to expedite their decomposition in advance. Special care should be taken not to cause excessive content of nitrogen.

(f) Removal of gravels ----- The investigation at Nojiri district has revealed that the amount of gravels removed by hand was $0.4m^3/10a$ on the average for five years after the execution of the field readjustment. According to the test made at Mikatagahara platean, Shizuoka Prefecture the removing cost of gravels was 12,000 yen/10a, corresponding to about 10% of reclamation cost of paddy field. It needs to remove the gravels in the surface soil during the execution of the field readjustment, and it is also important to take care not to mix the surface soil with the gravels in the soil layer beneath it.

E-2 Permeability

> The permeability of the soil layer will be such that the coefficiency of permeability of the soil layer with the least permeability is within the range of 10^{-4}-10^{-5} cm/sec.

[Explanation]

1. Basis

Where large machineries are used, it is desirable for the operation of them that the permeability of the soil in non-irrigation period is high with a good drainage resulting as well, whereas the extremely high permeability of the paddy field in irrigation period is not desirable in view of both the use of water resource and the growth of paddy.

The spacing and depth of irrigation ditches vary with the permeability of soil layer for the direct sowing dry field and with the permeability of subsoil layer, the position of ground water level and the spacing of under-drains for the puddling paddy field. In order to allow the seepage of 20 mm/day, a permeability of about 2 - 5 x 10 cm/sec is the lower-limit of that of that of the subsoil (including mold bed). Where a paddy field has a layer of soil, of which coefficient of permeability is less than 10^{-6}cm/sec, any variation in the hydraulic conditions has almost no relation to the seepage amount of that field. Even if the hydraulic condition such as the water level of the drain (hydraulic gradient) varies substantially, the seepage amount is no more than 10 mm/day with variation less than only 1 mm/day, thus the large machineries are often impeded in their operations in the harvesting period. Therefore, it is necessary that the permeability of the soil layer is within the range of 10^{-4} -10^{-5} cm/day for a soil layer having the lowest coefficient of permeability.

2. Method of Investigation into Present Status

It is measured by the plot survey of water requirement in depth about the time of "Nakaboshi" drainage. In carrying out the measurement of the plot water requirement in depth, the fields adjacent to the plot is ponded to the same extent so that there will be no border seepage and its outlet and inlet are ascertained so that no water flow in nor out. K-type water requirement test equipment is used in the measurement for the survey to be made prior to the executions of field readjustment.

3. Improvement of Soil Permeability

(a) Improvement of permeability by means of "Nakaboshi" drainage and intermittent irrigation ----- It is possible to increase the permeability by drying the soil and causing cracks by means of "Nakaboshi" drainage or the intermittent drainage. Even where the permeability cannot be increased only by the "Nakaboshi" drainage, the combination of underdrains and "Nakaboshi" drainage is effective in many instances.

(b) Improvement of permeability by means of dry paddy field direct sowing, paddy cultivation by irrigating field, and rotable paddy field ----- The introduction of the dry paddy field direct sowing, the paddy cultivation by irrigating field and the rotable paddy field promotes drying and crack generation of the soil because no water is ponded on the paddy field surface in the period of brisk evapo-transpiration. In particular, it is effective for increasing the permeability to introduce those cultivation system after the groundwater level has been lowered.

(c) Improvement of permeability by installing underdrainage system ----- Reference is made to the paragraph dealing with the under drainage.

(d) Other artificial improving method ----- In many cases the permeability of the soil is improved due to the cracks generated by drying the soil positively, but there is no assurance that such cracks can be always generated at any time and in any place. Some artificial methods are necessary to improve the permeability of soil where no crack is generated by introducing any of the above methods to dry the soil as far as the conditions permit it, or where the cracks cannot be used effectively for practical purpose due to the extreme lag in their generation. Effective for this are crumbling of subsoil, reversion, brought earth from another place, deep plowing and, in some cases, mole drain. On the other hand, where the permeability of soil needs to be reduced in view of the water resource and the growth of paddy, it is effective to practice subsoil compacting, to place brought clay or to use bentonite.

E-3 Groundwater Level

The groundwater level in the non-irrigation period will be about 50 cm or more below the field surface.

(Explanation)

It is necessary to lower the groundwater level about 50 cm or more below the field surface as a condition to enable the second cropping and to form the mold bed which constitutes the principal factor of the bearing capacity. The subsoil water level mentioned here is that at the center between the under-drains, being the average subsoil water level referring to the length of absorbing under-drains. The time needed tolower the groundwater level from the surface to 50 cm below it is set at 5 days or less, which seems to be the allowable limit for the purpose of introducing large farm machineries.

In measuring the subsoil water level, a hole is bored with auger from the field surface, as shown in Fig. 10, in which vinyl chloride pipe (with round holes or slits) is inserted with space between it and the hole wall filled with coarse sand; thus the pipe is buried in the free water of the soil. Several such measuring pipes are placed on the center line between the absorbing under-drains, to calculate the average level which is regarded as the groundwater level of that field.

Where the groundwater level is easily measurable and confirmable as such, the level after the completion of the field readjustment is presupposed in the course of planning to consider whether it will cause any impediment in respective stages of farm management. If any impediment is caused, the planning of open drainage or underdrainage is necessary for coping with it.

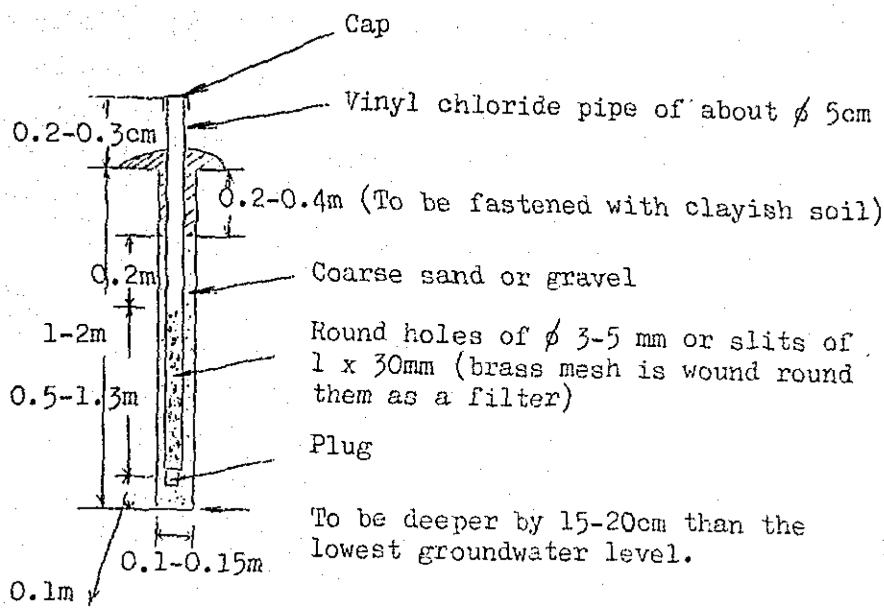


Fig. 10

Where it is difficult to measure and confirm the groundwater level as such, for example, as in the case of pushed water from the outside of the district or impermeability of soil, the crib test is executed at the place to practice the measurement taking account of any variation of the soil after the execution of the readjustment. For example, K-type water requirement test equipment is used for this purpose.

E-4 Grade of Flatness of Filled Surface

The accuracy of the surface flatness after the field readjustment will be in a range of ±5cm of the average elevation, and the gradient of the field surface should be flat or otherwise its drain side be lower.

[Explanation]

1. The accuracy of flatness is indicated by the differences from the average elevation measured by the 10 m section leveling.

2. It is desirable that the differences of elevation at all measuring point is at least in a range of ±5 cm of the average elevation, in view of the restriction on paddy cultivation. Even where the field surface slopes the difference of elevation within ±5 cm will keep the difference in the depth of ponded water in a range of 10 cm as between the irrigation canal and the drain sides. However, in consideration of the cost of field readjustment and the yearly uneven subsidence of field surface, it is allowable where the differences at all measuring points are within ±10 cm, with more than 80% of which being within ±5 cm.

At Takasu-wanaka District, Gifu Prefecture, the accuracy of flatness (as of May, 1964) and its yearly variation (at 660 measuring points) were measured, by 5 m section leveling, at the paddy field compartment of 7.5 ha leveled by three applications of a land leveler, after readjustment by a bulldozer. The following Table-2 shows a part of the results.

Different of Elevation	After readjustment by bulldozer	After leveling by land leveler	After 3 crops of paddy
±5cm or less	85%	88%	94%
±6 - 10 cm	15	11	6
±11 cm or more	3	1	0

It is difficult to secure the difference in elevations within 0.5 cm or less at all measuring points only by the bulldozer leveling, and even after the land leveler have applied the difference of elevations of ±6 cm or more still accounted for about 10%. It was only after three crops of paddy that the differences of ±5 cm or less in elevations narrowly accounted for 94%. The questionaire revealed that 85% of the repliers desire to make their paddy fields more flat.

According to a survey at Mizuma District, Fukuoka Prefecture, made at (1.5 ha, 608 measuring points) the difference of elevations within ±5 cm which accounted for 92% after one paddy crop decreased to 89% after three crops, showing that the flatness is not expected to improve so much through the yearly process and it can be rather deteriorated. The influences felt in this point are that the soil texture of this district is clayish, that both the cut and filled portion are found mixing in one compartments are divided in the lateral direction to the drain with each bordered block readjusted and leveled by cultivaters. For example, the survey made in November, 1966 (after three paddy crops) showed that the number of measuring points higher than the average elevation accounted for 75% on the cut portion and those lower than the average elevation for 73% on the filled portion, with a markedly uneven subsidence found in the latter portion.

3. The field is divided toward the drain side and the difference of elevations is ascertained to be within the abovementioned range for each compartment. It is necessary that the average elevations of two compartments are the same or that of the compartment on the drain side is lower. It should be taken into consideration at the time of reclamation that the surface become lower due to borrowing earth for road and the drain side part has a tendency to become higher yearly due to placing on it the excavated earth of the drain.

The paddy field surface needs to be at a slope in order to expedite the distribution of intake water from the inlet to reach all over it, and to drain the surface water from the outlet as perfectly as possible. Where the flatness of the field surface is poor and the drainage of the surface water is inadequate, a temporary drainage ditch is built. Where a compartment is more than 10a, spacing of under drains becomes coarser and flatness of field surface deteriorates, making it difficult to drain the surface water; on the other hand the necessity to remove quickly the ponded water on the paddy field surface becomes greater for improving the mechanized cultivation techniques in relation to machinery work, chemicals application, "Nakaboshi" drainage, pouring of liquid fertilizer, drainage in harvesting period, and irrigation and drainage in paddy growth period.

An example of the survey at Mizuma District shows that the portion on the drain side has often become higher, especially so where that portion is a cut protion. To meet this, the rebeled surface on the irrigation ditch side should be provided with extra-banking to fill up the anticipated yearly subsidence (2 - 5 cm), at the time of the readjustment work.

4. It is necessary not to make a broad area of high or low block as far as possible. Where the high and low blocks spreads all over a broad area making gentle slopes, a large amount of earth must be moved in order to make it flat in the process of agricultural management work.

5. In Nojiri District, Toyama Prefecture. (compartments each of about 0.6 ha, about 20 measuring points per compartment) has attained a fairly good accuracy of flatness, with the difference of elevations less than ± 5 cm being 100% after the readjustment,

96% after one crop (for the field readjusted in 1964), and 94% after two crops (for the field readjusted in 1963). The questionaire shows that few farmers has been satisfied with the flatness immediately after there-adjustment, but some seeked to improve the flatness by puddling through 2-3 crops (50%), or by taking such measure as transportation of soil in spring and autumn (14%), and some replied the improvement in the flatness year by year as a result of above measures (82%). On the other hand, some farmers replied that though the flatness is bad any special measures are not taken due to the restricted labor (34%). There are such obstructions, indicated to be due to the poor flatness, as bad drainage of paddy field surface (33%), uneven growth of paddy (31%), insufficient watering of paddy (19%) and insufficient effect of weeding agent (10%), in the case of transplantation system cultivation 2-3 years after the reclamation. In the case of direct sowing cultivation, in particular, as the germination rate is strongly influenced by "furiku", it needs to improve the inadequate flatness by means of transplantation.

6. Where the adequate flatness of a paddy field surface cannot be attained at the time of reclamation or by the puddling thereafter, it is necessary to resort positively to the underwater leveling method. In this, after having leveled the field surface roughly by transfering the soil with a bulldozer, the surface ponded with water may be finished by a leveller such as swamp bulldozer or land lebeler, or it may be lebeled by dragging about an electric pole and the like by cattle or machinery. As these methods mix up the soil under water, the soil structure deteriorates or the permeability of clayish soil becomes too small, in which case the permeability must be recovered by

"Nakaboshi" drainage.

E-5 Evenness of Subsoil Bed

The surface of subsoil must be even where field readjustment is executed.

[Explanation]

1. The standards for the evenness of paddy field are applied to the measuring method of flatness accuracy and the tolerance limits of the difference of elevations.

2. Where the cutting and filling is executed in a compartment, it needs to pay a special attention to the evenness taking account of any irregular subsidence due to such cutting and filling. Poor evenness of the subsoil will impede the dryness of the paddy field surface, resulting in unequal depth of brought in surface soil which causes irregular growth of paddy.

In an example of survey in Nojiri District, Toyama Prefecture, (paddy field readjusted in 1964) the difference in the elevations of foundation ground measured at 6 points in each of 31 compartments after the finish of the ground was ±5 cm or less of the average elevation, accounting for 97% with 3% being ±6 cm or more.

The distribution of the surface soil depth measured by a cone penetrater after one crop at the paddy field (in Nojiri District) readjusted in 1963 was as shown in Table-3.

Table 3

Depth of surface soil (cm)	15 or less	16-20	21-25	26-30	31 or more	Total
After execution (%)	2	10	39	31	18	100
After one crop (%)	2	20	42	25	6	100

The depth of surface soil, or 25 cm in average, after the execution of readjustment slightly decreased to 23 cm after one crop. Those of 15 cm or less and 31 cm or more decreased to 8% from 20%, showing an equalizing treand of the surface soil depth. But the depth smaller than 20 cm increased to 22% from 12%.

Table 4 Depth of Surface Soil
(Average of those at three points
in the shorter side direction)

Time	Cut portion											
After one crop	24	23	22	23	26	25	24	22	22	22	22	21
After two crops	23	24	27	27	27	25	20	19	19	18	21	22
Variation	+1	-1	-5	-4	-1	0	+4	+3	+3	+4	+1	-1

Time	Filled portion							
After one crop	23	23	27	27	25	30	37	28
After two crops	20	23	20	22	21	26	17	22
Variation	+3	0	+7	+5	+4	+4	+20	+6

3. In order to modify the "furiku" produced by the irregular subsidence of the cut portion and to keep the paddy field surface flat, the surface soil of cut portion must be transported. Since the subsoil of the cut portion containing gravels consti-

tutes a major abstacle to the above transportation, such subsoil necessitates to level its surface very carefully.

Table 4 is an example of survey about the depth of the surface soil of the field readjusted in 1963 (1-2 unit field block) in Nojiri District.

The depth of the surface soil, or 22.2 cm in average, after one crop (In September, 1964) slightly increased to 24.8 cm after three crops (in June 1967). Its reason is the influence of increase in the depth of surface soil by as much as 20 cm at the most, as shown in Fig. 11, due to subsidence of the subsoil bed at the filled portions, to the contrary of the decrease in such depth at some cut portions

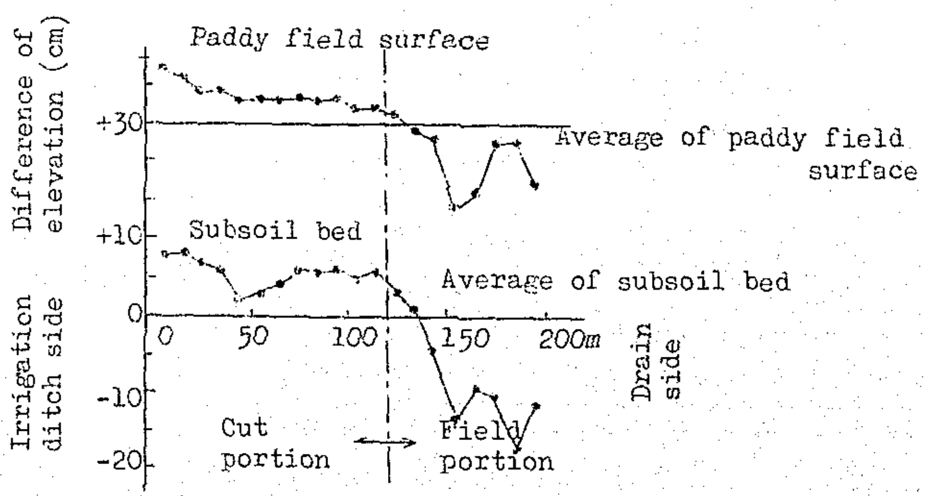


Fig. 11 Paddy Field Readjusted in 1963, Nojiri District (1-2 Unit field block, average of elevations at 3 points in the shorter side direction)
Survey conducted in June, 1967 (after 3 crops)

The drain side, being the filled portion, subsided and the surface of the paddy field slopes toward the drain side. The subsoil bed is also low at the filled portion and high at the cut portion, making a close correspondence with the former. The surface soil of this paddy field, maintains about the fixed depth of 25 cm in average, but it needs to transport the soil of the cut portion on the irrigation ditch side to the filled portion on the drain side in order to improve the flatness of the field surface modifying "furiku", with resultant decrease in the depth of surface soil on the cut portion. The other way, if the filled portion is on the irrigation ditch side, the gradient of the field surface will be contrary to that shown in Fig. 11; any measure to modify it causes an inevitable decrease in the depth of surface soil on the cut portion.

4. In the snowy region, it is effective to make the subsoil roughly uniform flat in autumn and improve it modifying "furiku" with the top soil replaced in spring.

E-6 Operation Possibility of Farm Machineries

E-6-1 Bearing Capacity of Field Block

(1) The bearing capacity of a field block is expressed by cone index after having performed static penetration test with cone penetrometer.

(2) The static penetration test will be performed preponderantly against the portion suspected to show a low bearing capacity based on the field investigation of a unit field block. In this, five or more measuring points are selected for one unit field block, and the test is repeated until roughly the

same trends and magnitudes of penetration resistance in the depth direction are obtained three times at least for one point and the average of these measured values will be adopted as the value of this point.

(3) The depth will be measured down to boom at the maximum below the field surface. However, 45 cm will suffice for finding the bearing capacity to operate farm machineries. In either case, the measurements will be performed at every 5 cm from the surface with the penetrating speed being 1.0 cm/sec.

Explanation

1. Expression of bearing capacity

(1) The index to express the bearing capacity of a field ground will be the cone index to be found by the cone penetrometer (with cross section of cone bottom = 6.45 cm^2 and point angle of 30^o) of which handling is simple and popular use is made in the civil engineering sector too. The cone index is the penetrating value of the bottom cross section.

(2) WES method ----- In measuring the main characteristics of the soil relating to the operation possibility of machineries quick and simply at the actual place, the Waterways Experiment Station (WES) finds the cone index with a cone penetrometer (with cross section of cone bottom - for clayish soil = 3.23 m^2, for sandy soil = 1.29 cm^2 and respective point angles of 30^o), on the assumption that bearing capacity and traction ability will be proportionate to shearing resistance of the traveled ground soil.

(3) Cone index ----- The cone index (Ic) is the unit load which

is applied to a cone to push it vertically in the ground, presuming the penetrating speed at 1 cm/sec for the case of (1) and 2 in/sec for the case of (2).

That is, it is expressed as:

$$Ic = \frac{\text{Push-in load}}{\text{Cross section of cone bottom}} \quad (kg/cm^2)$$

and that for (1) is expressed as Ic 6 and for (2) as Ic3.

2. Selection of Measuring Points and Determination of Measured Values

(1) Dispertion of measured values ----- In general, the coefficient of variation (c) is about 20% for the dispersion of measured values as to cone index, and the confidence number of measurements (n) is expressed as:

$$n = (ta^2.C^2)/P^2$$

In the above formula, t is Student's number and P is the tolerance of deviation from the population mean. If it is presumed that P = 10%, n will be n = 13, which shows that 13 times of measurements is needed at each measuring point.

Since 13 times of measurements at one point will require an excessive labor for measuring and be apt to yield personal errors, the determination methods of measured values which have been adopted empirically based on the surveys at various places are described here as standards for the present.

(2) It is an usual practice that large and heavy machineries are used for the readjusting work of paddy field ground. Therefore, where the investigation is made to find the extent of the influence on the crop cultivation given by the

compaction of a field soil due to the use of heavy machineries for the readjustment, as well as the degree of compaction of pillow land on which machineries travel frequently and that of field block due to the farm management by large machineries, such measurements are made for the range of depth down to 60 cm.

(3) The depth of critical soil layer, that is the soil layer which has the direct relation to the operation of farm machine vehicles, is correlated to the distribution of capacity in the soil profile and the types and weights of the vehicles. The distribution of capacity in the soil profile is of two types: the regular type of which cone indices remain at the same value or increase their values with the increasing depth, and the irregular type of which cone index at the deep place decreases than that of immediately upper side.

Where the soil layer is of the regular type, WES measures remolding index of the critical soil layer to find assumed cone index which is adopted as a criterion of the operation possibility of machineries. For the soil layer of irregular type, the remolding indices of the critical layer and of the soil respectively 15 cm upper and lower side of it are measured to find the minimum cone index from among them, which is adopted as such criterion.

As to the operation possibility for the farm works on a field, (i) the depth of the critical soil layer is generally 22.86-38.10 cm for wheeled vehicles of up to 22.7 ton in weight and crawlers of up to 45.4 ton.
(ii) As summarized in Table 12, even if the field of which average of $Ic_6(Ic_6(av))$ at the depth of 10-20 cm being 3 kg/cm or more is of the irregular type, vehicle travel-

ing for work is generally possible, but the field of this type of which mold bed has been once formed with $Ic_6(av)=$ 2 kg/cm^2 requires generally to fit vehicles with girdles. However, the traveling of vehicles for work is impossible where the soil layer is of the irregular type having 1.5 kg/cm^2 or less of $Ic_6(av)$ at the depth of 10-20 cm.

In view of the above description, the measurement of the cone indices are to be performed for the range of depth down to 45 cm for the purpose of deciding the operation possibility of machineries. In this connection, the dynamic clarification is still insufficient as to the traveling on the field of the irregular type, for which further investigation is expected in future.

(4) Transmission of vertical stress in the ground by load of running gears of farm work vehicle ----- The ground contact area of the tractor wheel is assumed to be equivalent circle and the load per unit area is expressed as q. If the vertical stress has a trend to concentrate to the load axis and is transmitted with critical distribution angle, its estimation where the groundwater level is low can be made by:

$$\nu\tau = q\,(1 - \cos \nu\beta)10$$

in this, τ - depth from field surface

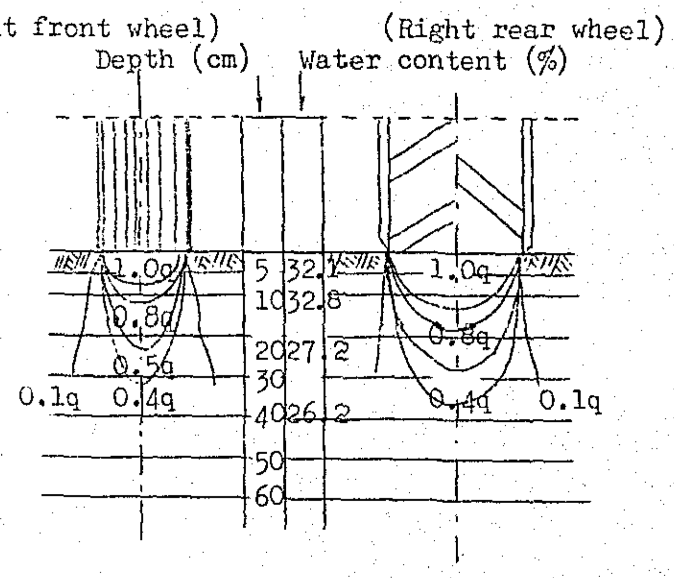
γ - unit weight of soil

ν - factor of stress concentration

β - angle (deg) made by a point on load axis and load edge

The results of calculations made in respect of 17 W Field of M zuma Model District show that = 126 cm, on the basis of radius of ground contact circle = 15 cm, = 4, and = 1.8 x 10^{13} kg/cm^3.

For an example, the distribution of the vertical stress stress (2) is shown in Fig. 12 which was drawn based upon the actual values in relation to the wheel load of F erguson MX35 wheel tractor at Mizuma Model Field 11 J3. The figure shows that the stress of 0.5 q was produced at smaller depth than 30 cm and the range showing 0.1 q was about 60 cm in depth. The cone indices varied greately at the depth of 0 - 16 cm due to the increase in density (decrease in void ratio) caused by the traveling of tractor.



q = Average load intensity

Fig. 12 Pressure Bulb under the Wheel of Tractor

3. Conversion of cone index

(1) The conversions of Ic_6 and Ic_3 between each other are necessary where the WES criteria are used with Ic_6 values or the criteria under Ic_6 are used with Ic_3 values. It is desirable to find the correlation between Ic_6 and Ic_3 in advance for each survey field.

(2) The following shows some examples of investigations made to find the correlation between Ic_6 and Ic_3.

1 $Ic_3 = Ic_6 + 0.41$ (kg/cm²)

2 $Ic_6 = 0.705\, Ic_3 + 0.091$ (kg/cm²)

The limits of application are $Ic_6 > 0.577$ (kg/cm³) and $Ic_3 > 1.12$ (kg/cm³).

These correlations were found based on 110 samples of Mizuma District, and the coefficient of correlation is $r = 0.78$.

E-6-2 Vehicle Operation Possibility

> The tentative standards prepared with the average values of Ic_6 (the bottom cross section of the cone used being 6.45 cm² with the point angle of 30°) at the depth down to 15 cm from the field surface to decide the possibility for working travel of the farm machineries are as follows. Theaarable land should have the values satisfying these standards.

(1) Where the Soil Layer is of the Regular Type

(i) Working Travel in Plowing and Harvesting Standard of Easiness for Working Travel in Straight Line

For no-load travel or rotar-vator plowing			
Average of Ic_6 at the depth of 0-15 0-15 cm (kg/cm^2)	Wheel tractor	Average of Ic_6 at the depth of 0-15 cm (kg/cm^2)	Wheel and crawler tractor fitted with girdles
4	easy	3	easy
4 - 3	possible	3 - 2	possible
3 - 2	difficult	2 - 1	difficult
2	impossible	1 1	impossible

Harvesting Travel	
Average of Ic_6 at the depth of 0-15 cm (kg/cm^2)	Semi-crawler combine
3.0	easy
3.0 - 2.5	possible
2.5 - 1.0	difficult
1.0	impossible or very difficult

(ii) Working Travel in Puddling

Where wheel tractor is used for puddling it is fitted with paddy field wheels, basket wheels or girdles. The satisfactory cone index (Ic_6) in this case is 3 kg/cm^2 in the average of those in a range of 10 cm immediately below the surface soil layer.

(2) Where the Soil Layer is of the Irregular type

To be treated as (1) - (ii) above.

(Explanation)

1. Many of the paddy fields in our country are of the irregular-

type soil layer as it is called here. As it is difficult yet to set standards for such soil layer, the above (1) - (ii) is applied to it.

2. Working Travel in Plowing and Harvesting

(1) It isdesirable to make the final decision coordinating the above-mentioned criteria as to the traveling of farm working vehicles in driven plowing and harvesting with the descriptions in 3 and 4 below. The reason is that no working ability in traveling in horizontal direction is not taken into account.

(2) Where the criteria of WES are applied, Ic_3 is to be used for paddy field soil (fine grain soil).

(3) Rough estimation of the bearing capacity by footprints is mentioned by Bekker, M.G. and others, and the standards as shown in Table 5 is proposed to decide the degree of easiness for working run of farm vehicles.

These criteria presumes a condition that the field soil is comparatively homogeneous in the vertical direction, and will not be applied where the land surface is dry or the top layer is very weak with firm layer at the depth less than 20 cm. It is deemed necessary to make decision basing on the experience.

(4) The findings at the Experiment Farm for Second Crop by Large Machineries, Fukuoka Prefecture, are shown in Table 6 as an example where there is no available data of the penetration tests by cone penetrometer or only the values of soil solidity measured by hardness meter may be obtained by reason of available instruments. In this table, the working run quality of tractor is classified in a range from easiness to impossible referring to the soil hardness. This

table shows that the soil hardness at the depth of 11-15 cm below the field surface has the most close relation to the movement of track, that is, where the solidity of this portion is 15 or more by yamanaka-type hardness meter the movement is easy and where the solidity is 12 it is slightly difficult to move.

Table 5 Vehicle Traveling Quality where Soil Property is roughly Uniform in the Vertical Direction

Depth of footprint (when standing on one foot) (cm)	Easiness of traveling			
	Wheel type		Crawler type	
	No-load run or driven plowing	Traction	No-load run or driven plowing	Traction
0 - 0.3	A	B	A	A
0.3 - 0.7	B	C *1)	A	B
0.7 - 2.0	C	D *2)	B	C
2.0 - 5.0	D	E *3)	C	D
5.0 - 9.0	E	F *4)	D	E
9.0 <	F	F *5)	E	F

Grade of easiness in traveling

A - Very easy

B - Easy

C - Slightly difficult

D - Difficult

E - Very difficult

F - Impossible

Note:

*1) It is the limit of working by rubber-wheel vehicle

*2) It needs to fit with wheels for paddy field or basket wheels.

*3) Turning of vehicle is difficult

*4) *Turning of vehicle is impossible.*

*5) Running gears sink and it is of course impossible to move forward nor backward as well as to get out of it without any help.

Table 6 Relation between Hardness of Soil (in Yamanaka-type Hardness) and Working Run of Tractor

Easiness of working	Easy Traveling		Slightly difficult traveling		Limit of traveling		Impossible of traveling	
Type / Depth(cm)	C	W	C	W	C	W	C	W
0 - 5	15	17	10	14	6	10	7	9*
6 - 10	12	18	5	16	7	11	7	8*
11 - 15	15	16	12	12	9	15	6	14
16 - 20	16	25	12	12	15	17	7	19
21 - 25	21	27	15	24	15	19	9	24

* Slipping and sinking have relation.

main machinery -- Crawler tractor 34PS
-- (Shibaura K-20) --------- C
-- Wheel tractor (Ferguson FE-35) ---------W

Work Machinery -- Bottom - plow (14" x 2) mounted on wheel tractor
-- Bottom - plow (12" x 2) mounted on crawler tractor
-- Bottom - plow (16" x 1) mounted on crawler tractor

3. Diminution Rate of Movement

It is desired that the diminution rate of movement is less than 2.0% for the working run of farm work machineries, on the basis of hard surface road.

(1) Expression of slip -- The traction speed (traveling speed) of a tractor decreases with the increase in traction resistance, and the operating efficiency decreases as well. Although the decrease in traveling speed is due to the decrease in the speed of engine, the most predominant cause is the increase in the rate of slip of tractor's driving wheels. This rate of slip is expressed as slip factor or diminution rate of movement. It is very difficult to find the true slip factor and the slip factor as it is called generally is the dimmution rate of movement.

Diminution rate of movement (%) = (1 - movement efficiency) (%)

= (1 - movement ratio) (%)

$$= 100\left(1 - \frac{\text{distance moved under load}}{\text{distance movel under no-load (*)}}\right)$$

or $$100\left(1 - \frac{\text{no. of revolution of driving wheel under no-load}}{\text{no. of revolution of driving wheel under load}}\right)$$

(*) For slip factor, it is the distance moved without any slip under no-load.

Therefore, the traction force of a tractor increases when the traction resistance increases and the slip of driving wheels increases as well. In general, the diminution of movement and the grade of easiness of vehicle traveling and traction is as shown in the following table:

Table 7 Diminution of Movement and Vehicle Traveling and Traction

Diminution of movement (%)	Easiness of vehicle traveling and traction
< 20	Possible
20 - 30	Difficult
30 <	Very difficult - impossible

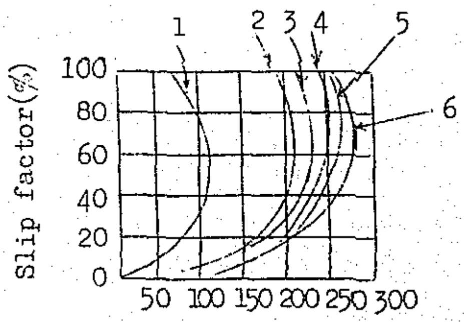
(2) Water Content of Top Soil and Slip

On the field where stabilized mold bed is formed at Mizuma Model Field, a clear correlation was seen between the water content of surface soil (0-5 cm) and the diminution rate of movement. That is, the diminution rate of movement increased with the increase in the water content, and the former showed 20% as against the latter of about 45%. Where the water content was more than 50%, the traveling of work vehicle was difficult even under no-load. However, the water content was more than 70% when the rotary plowing was performed.

The following is the relation between the average water content of the top soil and the diminution rate of movement at the time of the plowing run by Shibaura S30 and Fiat 411-R wheel tractors in the reclamation district (Ariake, Minami-kawazoe and N shi-Kawazoe polders) of the alluvial paddy field zone Saga Prefecture.

That is, plowing work is difficult in many cases on the field of which the model bed is not yet stabilized, even through the diminution rate of movement is limited to less than 10%. That the higher water content of the top soil, as compared with that of Mizuma District abovementioned, allows plowing run is due to a tendency that the diminution rate of movement is reduced by the propulsion force of the driven plowing instrument; the work is often impossible rather due to the increase in load caused by sticking of cohesive soil. Therefore, any decision cannot be made based on the diminution rate of movement in the case of such weak ground and it is made mainly on the basis of the sinking depth (see paragraph 4 below.)

(3) Tractive force -- The relation between tractive force and slip of centain tractor shows larger changes due to the variaticns in the soil condition than due to the variations in the traveling speed under the same soil condition, and the maximum tractive force varies as well. When the slip exceed a certain limit the increment ratio of the tractive force decrease (Fig. 13).



1. Alluvial paddy field (water logging)
2. Alluvial field
3. Diluvial field
4. Concrete road
5. Gravel road
6. Alluvial paddy field (well-drained)

Fig. 13 Tractive Force and Slip Factor (Kaburagi)

The wider tyres of the driving wheels of tractor produce greater tractive force than the narrower tyres, and wheel weights and girdles when fitted reduce the diminution rate of movement and improve the traction ability.

It is desirable to operate a tractor under the condition where the tractive horsepower of that tractor can be used most effectively, also taking account of its tractive speed (Fig. 14).

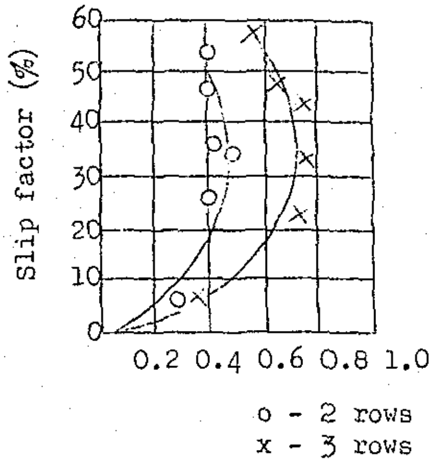


Fig. 14 Tractive Horsepower and Slip Factor (Kaburagi)

It is necessary to define the practice maximum tractive force by soil properties as it (tractive force at the common limit of slip) varies with the soil conditions. Tractor heavier in its weight produces greater practical maximum tractive force where the soil conditions are same, but the traction coefficient at the slip of common limit (practical maximum tractive force/driving wheel static load) shows nearly uniform values.

If the values of Table-8 are known, an estimation can be made from:

Table 8 General Values of Traction Coefficients by Soil Properties

(a) Paddy field

Soil conditions -- Cumulous deposit, drained immediately before the test, water content - 34.0-42.5(%)

	Traction coefficient	Traction ratio
Rubber tyre wheels	0.556	0.403
" fitted with girdles	0.797	0.482

(b) Field (J. W. Shield)

Soil conditions	Traction coefficient
Cumulous deposit	0.65
Loan	0.50
Sandy loan	0.40
Dry sandy soil	0.30

(4) Application of WES method -- The main factors which generally have influences on the tractive effort of the plow are 1 size of cut soil cross section (plowing depth and width), 2 shape of plow body, 3 plowing speed of plow, 4 soil property and status of soil surface and 5 tractive relations. Table 9 shows the examples of measurement made in relation to soil properties which cause great variations in the tractive force.

Table 9. Resistivities by Soil Properties

Example of measurement in U.S.A.				Example of measurement in Japan	
Soil classification	Soil Status	lb/in^2	kg/cm^3	Soil classification	kg/cm^3
Sandy soil	-	3	0.21	Peat	0.15-0.25
Sandy loam	Wet	3 - 4	0.21-0.28	Volcanic ash	0.16-0.25
	Dry	4 - 6	0.28-0.42		
Loam	Wet	5 - 6	0.35-0.42	Sandy soil	0.20-0.25
	Dry	6 - 7	0.42-0.49		
Clay loam	Dry	7 - 8	0.49-0.56	Loam	0.30-0.50
Heavy clay	Dry	9 -10	0.63-0.70	Acumulous deposit	0.50-0.60
	Lawn	10 -11	0.70-0.77		

There are three sizes of board plows: 12 in (30.5 cm), 14 in (35.5 cm) and 16 in (40.6 cm), among which the 14 in plow has been most popular.

As an example, where a tillage of 15 cm in depth is performed by 35 PS wheel tractor (3,223 lbs = 1,451 kg in weight) using the 14 (in) x 1 plow, the load needed to draw the plow is 320 kg presuming that the resistivity of the field soil is 0.65 kg/cm^3 (Table 9).

If it is assumed that 1R = 0.7 at IC_3 =6.8 kg/cm^2 (the bottom cross section area of the cone used is 3.23 cm^2) of the critical layer after the harvest at the center of under drains of 17E Unit Field Block in Mizuma Model Field:

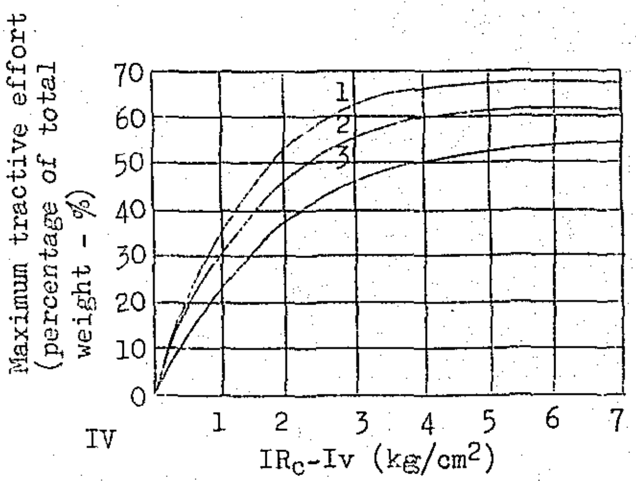
IR_c = 4.76 kg/cm^2

Also, where Iv = 53 lb/cm^2=3.71 kg/cm^2 of 35 PS wheel tractor and the curve of wheeled vehicle of Table 15 are used, the maximum tractive effort per centage of weight) for

IR_c - Iv = 1.05 kg/cm^2 being 25%,

1.451 (kg) x 0.25 = 362.8 (kg).

That is, since 62.8 (kg) is larger than 320.0 (kg), 35 PS wheel tractor can well draw the 14 (in) x 1 board plow, at plowing depth of 15 cm, under this field conditions.



1 Caterpiller tractor with projections of more than 3.8 cm in height.

2 Caterpiller tractor with projections of less than 3.8 cm in height.

3 Wheel tractor

Fig. 15 The maximum Tractive Force of Self-propelling Vehicle on Fine Grain Soil

(5) Fitting with wheel girdles -- The tractive performance of tractor is considered in the following, in reference with the traction of plow and harrow.

Flow with good turning over performance with the tilling depth of 15 - 20 cm is to be introduced, presuming the tillage after combine has been used, and it will constitutes one of the important items in the use of wheel tractor on paddy field.

The practival maximum tractive force where the girdles are fitted is greater by about 40% than where they are not fitted. But this effect cannot be expected where the soil contains extremely great amount of water. Therefore, where heavy work such as plow tilling is executed wheel weights are fitted, and wheel girdles are fitted in addition if it needs to increase the tractive force even though the manoeuvrability of vehicle reduces.

Table 10 Increase in Practival Maximum Tractive Force by fitting the Vehicle with wheel fircles (Takeda)

(Soil conditions -- cumulous deposit, water content of about 36%)

Type of Vehicle	No wheel girdle fitted	Wheel girdles fitted	Increase rate of tractive force	
Fordson Dexter	635	900	+42	+49 in average
Ferguson FE 35	500	830	+66	
Inter B275	690	920	+33	
Devid Brown	710	1100	+55	

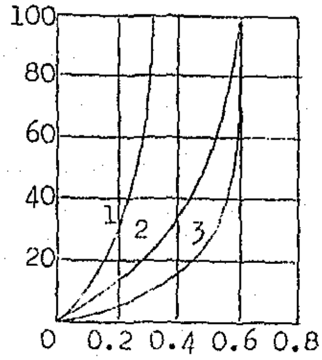
The diminution rate of movement was reduced markedly by fitting with girdles, and in the case of Takasu Model Field it decreased to half of that where the girdles were not fitted. The effect of fitting with girdles are remakable for the mixed soil of cumulous deposit and sandy soil. Table 11 shows the diminution rate of movement by kinds of soil.

Where the field is of dry and firm soil, the tractive ratio of wheel tractor fitted with wheel girdles and that of rubber wheel show only little difference. Where the field is of clayish soil containing large amount of moisture, the wheel girdles have an marked effectiveness (Fig. 16). The use of semi-crawler or crawler tractor is more effective in such case.

Table 11 Diminution rate of movement of tractor's Driving Wheel by Kinds of Paddy Field Soil and with or without Girdles fitted

Without girdle					
Cumulous deposit			Sandy soil		
Depth of tillage (cm)	Traveling speed (m/sec)	Diminution rate of movement(%)	Depth of tillage (cm)	Traveling speed (m/sec)	Diminution rate of movement(%)
14.3	1.37	30.33	13.2	1.50	15.37
18.2	1.27	33.33	19.1	1.43	21.25
25.6	1.04	41.76	22.7	1.45	16.49

Without girdle			With girdles fitted		
Mixed soil of cumulous deposit and sandy soil			Mixed soil of cumulous deposit and sandy soil		
Depth of tillage (cm)	Traveling speed (m/sec)	Diminution rate of movement(%)	Depth of tillage (cm)	Traveling speed (m/sec)	Diminution rate of movement(%)
16.3	1.29	16.1	15.2	1.60	3.95
18.0	1.23	25.0	18.1	1.67	7.12
21.7	1.11	31.0	21.0	1.62	7.77



Rubber wheels with girdles fitted Semi-crawler

Note: Diminution rate of movement was calculated on the basis of traveling under no-load in tractive work on the field.

Fig. 16 *The Effect of Girdles on the Field of* Comulous Deposit containign Large Amount of moisture

(6) Examples of *Traveling Phenomena in Tractor Working* (at Takasu-wanaka and Mizuma Model Field)

(1) Where the mold bed has been formed and stabilized in the paddy field, with $Ic_6 = 2.0$ kg/cm^2 shown at the depth of 5 cm and the average of Ic_6 at the depth in a range of 10 - 20 cm being more than 3.0 kg/cm^2, a tractor is capable to travel on it even though making slips.

(2) Where, although its mold bed has been formed once, the paddy field is of such irregular type that the cone index is $Ic_6 = 1.0$ kg/cm^2 and "the average of cone indices at the depth between 10 - 20 cm is Ic_6=2.0 kg/cm^2 or" "that at the depth between 10-15 cm is Ic_6=2.0-2.5 kg/cm^2" but is less than 2.0 (kg/cm^2) at the lower depth, the traveling of tructor will cause slips and sinking of running gears. Such paddy field requires adequate attention to any deterioration of

its bearing capacity due to broken mold bed caused by the use of paddy field wheels with high lugs or by deep plowing.

The above may be shown in a type specimen manner in the following Table 12.

(3) Surface soil is of Ic6 = 0.5 (kg/cm^2) and the existence of plowsole is not distinct. When the average value of Ic6 in the depth of 10 - 20cm is between 1.5 (kg/cm^2) and 1.7 (kg/cm^2), the passage of machinery will subside and the use of tractor will be extremely difficult or almost impossible.

Table 12 Traveling Phenomena of Tractor
(Unit of Ic_6 - kg/cm^2)

<table>
<tr><td>Ic_6 ≈1.5</td><td>Ic_6>2.0</td><td colspan="2">Ic_6> Average 3.0</td><td>Mold bed stabilized (capable to travel even making slips)</td></tr>
<tr><td rowspan="2">Ic_6 ≈1.0</td><td rowspan="2">Ic_6< Average 1.5</td><td colspan="2">Ic_6= Average 2.0</td><td rowspan="2">Ic_6>2.0-2.5
Mold bed unstabilized (slips, sinking, and difficult traveling).
Use of paddy field wheel and deep plowing cause breakage mold bed</td></tr>
<tr><td>Average 1.2-1.3</td><td>Avera 2.0-2.5</td></tr>
</table>

Ic_6 =0.5	$Ic_6 <$ Average 1.0	Average 1.5-1.7	Ic_6 does not increase	Mold bed is not clear Large extent of sinking Impos-sible of operation

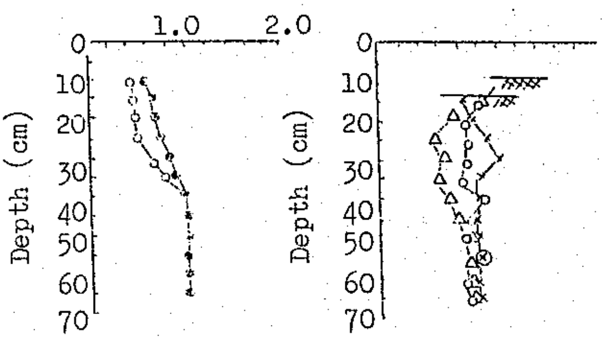
4. Sinking of running Gears of Farm Work Vehicle

The desirable depth of sinking (depth of wheel track) is less than 5 cm for the running gears of farm work vehicle at the time of farm work, taking into consideration the influence upon the growth of crops due to tearing up of field soil.

(1) Disturbance and compaction of field ground by traveling vehicle

The sinking of running gears of farm work vehicle reduces the farm work efficiency, and where the field is weak the wheel track is so intensified that tearing up of soil deteriorates the physical property of soil and causes compaction of it, giving bad influences on the cultivation of crops. Therefore, it is desirable that the depth of sinking of running gears is less than 5 cm.

The findings at Mizuma Model Field as to the variation in compaction of field ground due to the traveling of large work machineries shows that any influence is hardly notice-able on the cone indices at the depth below than about 40 cm where the field ground is of regular type, and that the travelings up to 25 times disturb the ground soil. But where the traveling times reach as much as 50 times, com-pactive effect is seen (Fig. 17). Where the mold layer is weak, tearing up of top soil is particularly remarkable.



Water content of field soil --------- 36.5 - 45.3%

Field ground --------------------------- Regular type

o ------------ Travelings 5 times

● ------------ " 10 times

△ ------------ " 15 times

○ ------------ " 25 times

× ------------ " 50 times

Fig. 17 Comparison of Cone Indices Before (Ic_3a) and After (Ic_3b) Travelings of Wheel Tractor

(2) Outline of Impediments to Farm Work (Example at Mizuma Field)

The mold layer on which the sinking of vehicle running gears is more than 10 cm is in many cases high in its water content and its average values of Ic_6 at the depth of 0, 5, and 10 cm is less than 1.2 kg/cm^2.

In the farm work on the field having the mold of such soil property:

(1) Bottom plow, plow with harrow -- Much earth sticks to

them due to weak soil, standstill time and turning time during the work increase, and their soil breaking effect is poor.

(2) Rotary tiller -- It becomes ill-balanced due to sticking mud, its rurns are difficult and it is danger to lift the work instrument during traveling as the front wheels of tractor are caused to float off. Also, frequent removing of mud and inspection of tiller times are needed.

(3) Tooth harrow -- Breaking soil and harrowing is difficult (or impossible).

(4) Combine -- Although the field was damp and weak with some locally standing water, with the water content of its top soil being 40%, the cultivation conditions were good. Due to the weakness of the top layer soil, it was difficult to operate even the semi-crawler combine (Laberda M75R combine) and it needed 3-4 switchback operations to make 90° turn. Wheel combine is impossible to make working run but crawler-type combine can make stabilized traveling (Crawler type is suitable to harvesting work on the paddy field of weaker soil.) The investigation was made into the operational limit of crawler combine on the damp and weak field, and it proved that its operation and turns were difficult with the running gears sinking about 30 cm due to very damp and weak soil with water content of 48-52%. The time required for turns accounted for 15-30% of the total work hours due to repeating of switchback operations for several times.

(3) Sinking in Tillage Operation

(1) Where wheel girdles are not fitted with (example at

Takasu-wanaka)

The places where the running gears of tractor sank in its tillage operation were those of which cone indices at the depth of 0-5 cm were less than 2.0 kg/cm^2 and they were generally less than 3.0 kg/cm^2 at the depth in a range of 10-20 cm. Therefore, it can be looked upon that the limit for sinking of the running gears is Ic_6 3.0 kg/cm^2 at the depth of 10-20 cm.

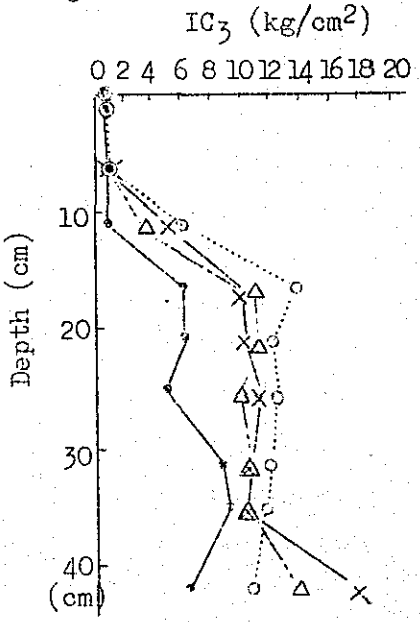


Fig. 18 Cone Indices (Ic_6) and Sinking in Travelling under No-load or in Driven Tillage

Sinking depth of running gears (cm)	Cone index at the depth of sinking (Ic_6 kg x cm^2)
26	1.8
13	1.6
7	2.3
5	1.9

Fig. 18 shows an example of measurement of the cone indices and sinking in traveling under no-load or in driven tillage operation.

The details are as follows:

(i) Ic_6 ranges 0.4-2.0 kg/cm^2 over the entire soil layer, and the sinking depth of the running gears was 26cm. Ic_6 at the depth of 26 cm. Ic_6 at the depth of 26 cm is 1.8 kg/cm^2.

(ii) Ic_6 of the top layer was small but that at the depth of 20 cm was 2.4 kg/cm^2, with the sinking depth of the running gears being 13 cm. Ic_6 at the depth of 13 cm is 1.6 kg/cm^2.

(iii) Ic_6 at the depth of 10-20 cm was 3.19-3.14 kg/cm^2 and the sinking depth of the running gears was 7 cm. Ic_6 at the depth of 7 cm is 2.3 kg/cm^2.

(iv) Ic_6 at the depth of 10 cm was 2.77 kg/cm^2, showing the highest among those measure at various depth in this soil layer, and Ic_6 at the depth of 20 cm was 2.36 kg/cm^2, with the sinking depth of the running gear being 5 cm. Ic_6 at the depth of 5 cm is 1.9 kg/cm^2.

(2) Where wheel girdles were fitted with

The sinking depth of the running gears under no-load operation on cumulous deposit field (with water content of 34.0%) was 4.0 cm with girdles fitted and 6.0 cm with bare tyres not fitted with them (increasing by 50%).

Also the vehicle fitted with girdles have good turning ability in stabilized operation, with smaller turning-radius.

(3) Fig. 19 and Fig. 20 show the example in Toyama Prefecture about the relation between the cone indices and the sinking depth in the straight traveling and that between the sinking depth in straight traveling and such in turning, as referring to whether the wheel girdles were fitted with or not.

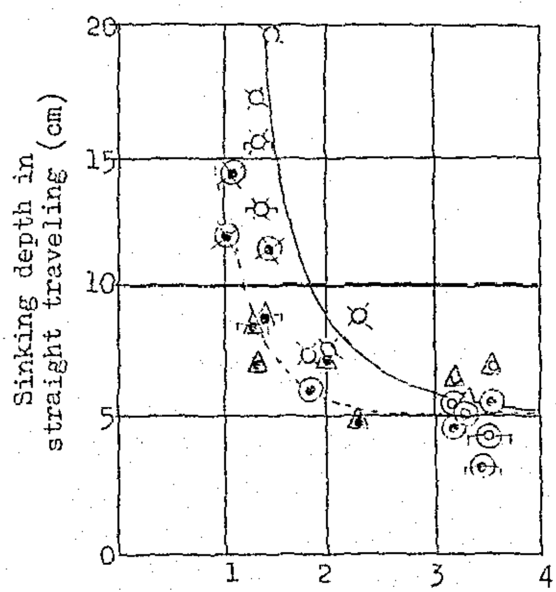
(i) Cone indices (Ic_6) and sinking depth in straight traveling -- If the sinking depth ranging to 7 cm is allowable for straight traveling, in the case of Fig. 19. working run was possible with the average of Ic_6 at the depth down to 15 cm being more than 2 kg/cm^2 for the vehicle fitted with girdles, and with that more than 3 kg/cm^2 for the vehicle not fitted with girdles.

(ii) Sinking depth in straight traveling and that in turning - As shown in Fig. 20, the sinking depth in straight traveling (x) and that in turning (y) have the following relation:

$$y = 1.3 x + 1.3$$

Therefore, where any farm work is regulated by the sunk surface, the shinking depth in turning takes precedence over that in straight traveling. If a depth of more than 7 cm is allowed for the sinking in straight traveling the sinking in turning will be more than 10 cm, with resultant tearing up in excess of the pillowland. If the sinking depth at the pillow land is regulated within 5 cm, that in straight traveling will be about 3 cm, and the influence of torn up soil on the crops be negligible.

-O-	wheel with tyre	○ :	easy
⌐¬:	*field with mold bed*	△ :	*slightly difficult*
--⊛--	girdle equipment	× :	difficult



Ic_6 (average at the depth of 5-15 cm) (kg/cm^2)

Fig. 19 Cone Indices and Sinking Depth in Straight Traveling

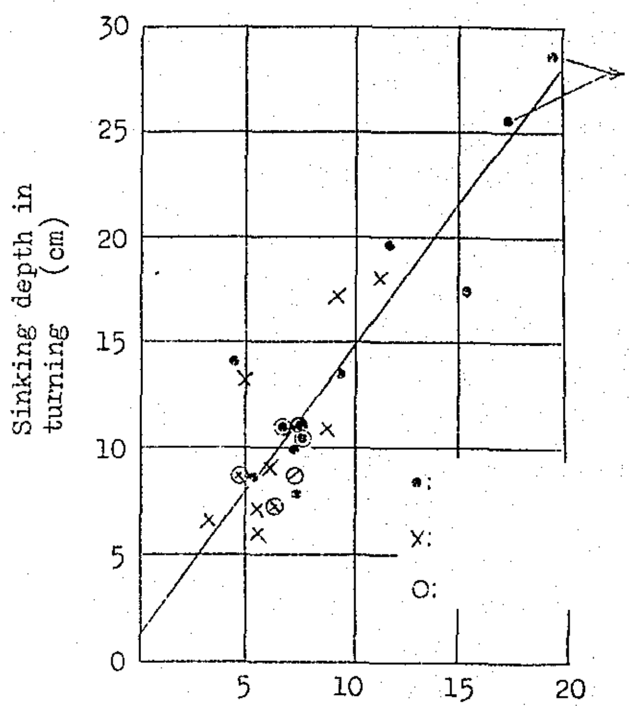


Fig. 20 Relation between Sinking Depth in Straight Traveling and that in Turning

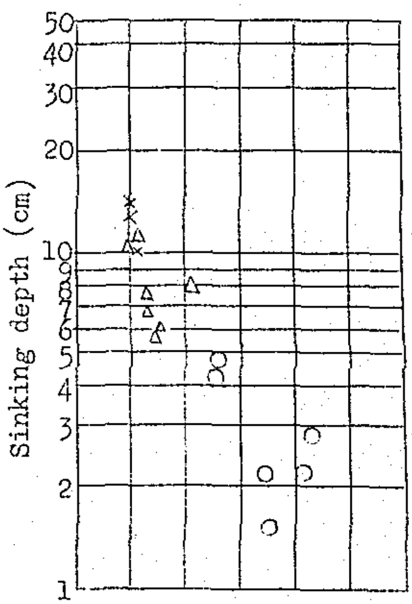
(4) Sinking of work vehicle on the field of alluvial clay -- Fig. 21 and Fig. 22 show the results of investigations into the relations of sinking of the running gears of work vehicle with cone indices (Ic_6) and easiness of working, which were carried out at the fields on the polder around Saga Prefecture which may be called as typical weak fields. The work vehicles used for the tests were wheel tractor and semi-crawler combine; the former being Fiat 411-R(40.5 PS) and Shibaura S-30 (30.5 PS) respectively fitted with peg-tooth rotary, and the latter being clayes M80.

In the tillage operation on the weak paddy field with much sinking of vehicle, there are many cases where the continuous operation at the required revolutions is unreasonable by reasons of load on the rotary, making the tillage work difficult or impossible.

Basing on the above, the relations of the sinking of vehicle to the driven tillage and the harvesting work is reduced to Table 15.

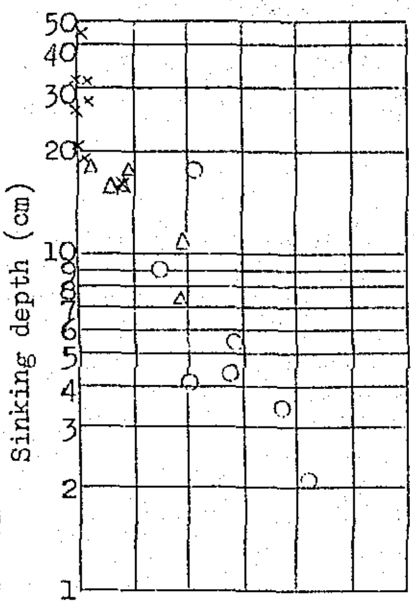
Table 15 Sinking in Tillage Operation by Wheel Tractor and in Harvesting Operation by Semi-crawler Combine and Easiness of Working (in straight traveling on regular type soil layer)

Tillage work by wheel tractor		Easiness of Working	Harvesting work by semi-crawler combine	
Average cone indices at the depth ranging to 10 cm Ic6(av)(kg/cm^2)	Sinking of running gears		Average cone indices at the depth ranging 15 cm Ic6(av)(kg/cm^2)	Sinking of running gears
>2.5	< 5	Possible	< 2.0	< 6 - 7
2.5 - 1.3	5 - 10	Difficult	2.0 - 1.0	7 - 15
1.3 >	10<	Very difficult - impossible	1.0 >	15 <



Average values (kg/cm^2) of cone indices (Ic_6) at the depth ranging to 10 cm

Fig. 21 Relation between Cone Indices (Ic_6) and Sinking Depth of tractor while in Driven Tillage Operation



Average values (kg/cm^2) of cone indices (Ic_6) at the depth ranging to 15 cm

Fig. 22 Relation between Cone Indices (Ic_6) and Sinking Depth of Combine while in Working Run

○ Working run is impossible

△ Working run is difficult

× Working run is very difficult or impossible

(5) Sinking depth of running gears and traction -- Where the top soil is of firm clayish with high water content, the diminution rate of movement is great though the sinking of

running gears is small. On the contrary, where the top soil is very weak with firm mold bed lying in its sub-layer, the diminution rate of movement is small though the sinking is great. Therefore, the easiness of working must be decided on the basis of the conditions which show the lower value of either diminution rate of movement or sinking depth. The general standards for deciding the easiness of working are shown in Table 16 in connection with the sinking of the running gears and the traction.

Table 16 Sinking of Running Gears and Easiness of Traveling and Traction

Sinking depth of running gears (cm)	Easiness of traveling and traction
< 5	Possible
5 - 10	Difficult
$10 <$	Very difficult - impossible

5. Traveling of Tractor at the Time of Puddling

(1) Traction by wheels fitted with tyres under the flooded field condition -- Fig. 23 has been obtained as a result of test conducted using wheels with tyres as to the relation between the diminution rate of movement and the tractive force. Since the diminution rate of movement is about 20% with tractive force being around 130 kg. on the field with the mold bed of 20 cm in depth, it cannot be said that the tractive force is adequate for puddling. Therefore, it needs to fit with paddy field or basket wheels

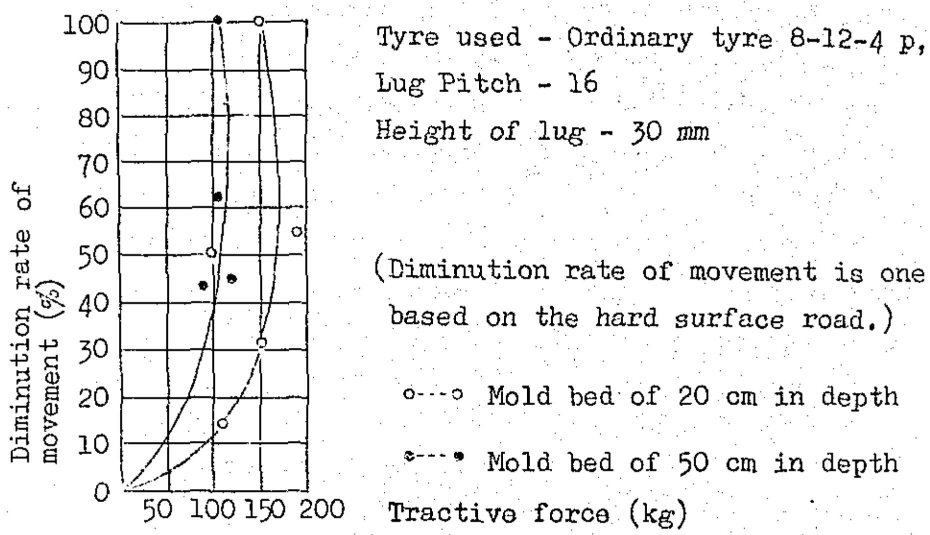


Fig. 23 Diminution Rate of Movement and Traction Force under the Flooded Field Condition

(2) Wheels to be fitted for Puddling

(1) Where paddy field wheels are mounted directly on the axles after having demounted rubber wheel.

The smaller the lug angle is the better the running performance is, with smaller running resistance and sinking depth, but the mud sticking to the lugs has strong influence on the driving of tractor. With the lugs 50° in angle and 5-10 cm in height, the sinking depth of the running gears is great, but as, on the other hand, the diminution rate of movement reduces the tractive force is great. The influence of the height of lugs on the tractive force shows larger rate of increase up to 10 cm in height of lugs, with reduced diminution rate of movement. But excessively high lugs have deficiencies such as that the mold bed is broken or the front wheels float up when traction load is applied with danger accompanying.

Thus, the height of lugs deemed proper generally is 10 cm and the proper angle of lugs is 30° for cumulous deposit (heavy clay) and 50° for sandy loam; it may be said that paddy field wheel with such lugs has superior performance (see Table 17).

(2) Where rubber wheels are fitted with basked wheels (example at Mizuma Model Field).

The cone indices of the field ground on which puddling was possible by the tractors (Ferguson MX-35 and Fiat 411-R) fitted with basket wheels were more than 4.0 kg/cm^2 in average at the depth ranging 11-21 cm (Fig. 24) and more than 2.9 kg/cm^2 in general average.

Usually, the puddling by a wheel tractor is more easier when the water application is completed in shorter hours. Where many hours are needed for water application or the field remains in flooded condition for several days, difficulties will increase for the working. In this it needs to pay special attention to the field to which deep plowing is applied.

Table 17 Example of Diminution Rate of Movement, Tractive Force and Sinking of Wheel of Paddy Field Wheel

Tractor used - Fordson, Super Dexter (39.5 ps)

Field soil - Cumulous deposit

Height of lug - 5 cm

Angle of lug (deg)	Water content of soil (%)	Running speed (m/s)	Running resistance (kg)	Diminution rate of movement (%)	Tractive force (kg)	Sinking depth of wheel (cm)
30°	50.0	0.44	970	20.0	1050	18.4
40°	41.6	0.22	1500	21.6	1170	25.7
50°	41.6	0.19	1500	21.6	960	27.4
70°	39.5	0.32	870	29.0	1060	23.5
90°	37.9	0.33	1650	29.7	960	29.5

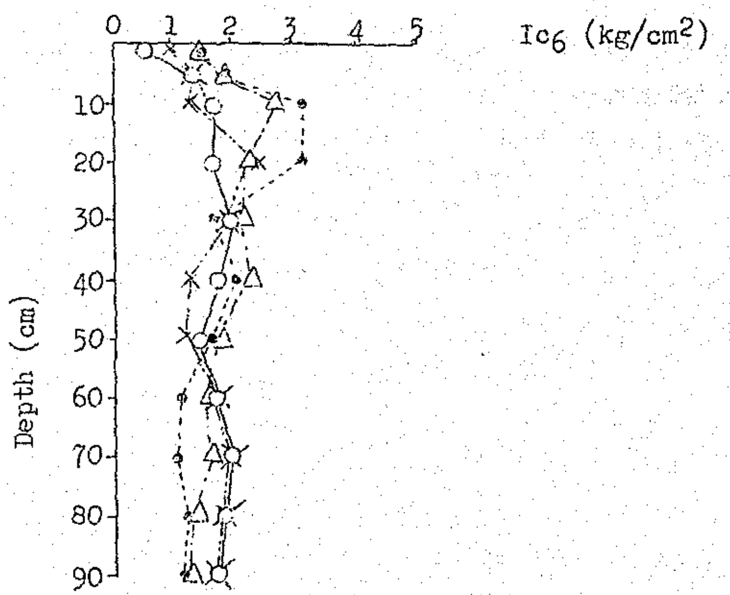


Fig. 24 Example of Cone Index (Ic_3) of Paddy Field at the Time of Puddling at Mizuma 17E Field (July 5th, 1966)