SURVEY OF THE WORKING CONDITION OF USED DISC PLOUGHS IN SOME SELECTED LOCAL GOVERNMENT AREAS OF NIGER STATE.

BY

RABIU D. IDRIS
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TABLE OF CONTENTS

APPROVAL PAGE

Having gone through this research work carried out by R. D. Idris, it is our opinion that it is up to standard of the requirement for the award of Post. Graduate Diploma in Agricultural Engineering (Farm Power and Machinery Option), Federal University of Technology Minna.

______________________	______________________
DR. MOHAMMED G. YISA (SUPERVISOR)	**DATE**
______________________	______________________
DR. MOHAMMED G. YISA (Head of Department)	**DATE**
______________________	______________________
(EXTERNAL SUPERVISOR)	**DATE**

DEDICATION

This study is dedicated to my family.

Finally, I wish to thank Mr. John Alabi of Agric. Engineering Department of The Polytechnic, Birnin Kebbi for all the assistance rendered during the course of this program.

And my appreciation go to Muhammed Mashayabo of zonal Agric Workshop for all the assistance given during the time of conducting this project.

ABSTRACT

The working condition of 114 used disc ploughs of different ages and makes was examined. The result show that 81 (71.1%) of the total number of ploughs were in working condition even though 69 (60.53%) of them were, resently, rehabilitated by either the patroleum Trust Fund (PTF), organization or owner, 33 (28.95%) were not in working condition while 25 (21.93%) were obsolete Among the major working parts (discs, shafts, bearing, furrow wheels, etc) of the ploughs that were examined, the bearing was discovered to be the one which poses frequent and serious problems to the farmers in the operations and management of their ploughs because of its high cost (up to N2500.00 per set) vital function in the optimum performane of the plough and rate of damage. Out of the 114 ploughs, the set of bearing in 33 (28.95%) were not in working condition and 25 (21.93%) of them had their sets of bearing removed while 8 (7.02%) had their bearings intact but they were not in working condition. Among the 81 sets of bearings that were in working condition, 69 (60.53%) of them were newly replaced ones. In addition to this the working condition of the other majotr parts of the ploughs were examined and assessed. In a bid to solve the problem of bearing and hub of the disc plough, another bearing (sleeve bearing was designed. It is to be use as a substitute to the rolling contact bearing of the disc plough. Babbit metal is selected as the bearing material. Models of the bearing and hub were cast. Sleeve bearing, made up of babbit metal, is cheaper, easy to maintain, more advantageous and durable than the rolling contact bearing.

CHAPTER ONE

INTRODUCTION

1.1 Disc ploughs are suitable for the tillage of virgin and stony soils, since roots are more easily cut by disc than my plough shares, and when discs come up against boulders they slide aside or roll over them. Although the quality of tillage under these conditions is inadequate, cultivation by moldboard plough would in such cases be simply impossible.

Disc ploughs are generally used in tropical and subtropical countries where bushy plants grow quickly and cover the arable soil; moldboard ploughs are not able to cut through the roots. They suffer frequent damage, or repeatedly become unhitched from the tractor.

The disc plough is the most common tillage implement used in Northern Nigeria because of its suitability to the nature (structure, texture, consistency, etc) of the soil. The function of the plough is to cut and separate a layer of soil from underlying subsoil and invert it to bury any vegetation, crop residue or manure present on the surface.

Hundreds of used disc ploughs can be seen, lying idle, in many places because of one problem or another. In view of this, a survey of their working condition was conducted in some selected local government areas of Niger State in order to identify the parts which get damaged more frequently and the causes of such damage, with a view to finding means of minimizing or eliminating the problem. The survey covered 15 local government Areas of Niger State. A questionnaire was designed and distributed to many private and governmental farms. The responses were collected and analyzed. During the course of the survey, many causes of being failures were identified. The failures were as a result of improper care and maintenance as well as unsuitability of the type of bearing (rolling contact bearings) in use, considering the type and composition of the soil, climate and bebaviour of mankind in this area

Farmers were enlighten on the importance of proper and regular care and maintenance of disc ploughs in order to minimize the constant damage of bearings. Also an alternative bearing and hub , were designed and models were constructed. The new bearing is meant to substitute the present rolling contact bearing of the disc plough.

CHAPTER TWO

LITERATURE REVIEW

2.1 DISC PLOUGHS

Disc plough bear little resemblance to mouldboard ploughs, for a large revolving concave steel disc replaces the share, coulter and mouldboard. The disc is set at an angle to the line of travel, and it tuns a furrow slice to one side with a scooping action. The usual size of the discs is about 24 in (610 mm), and these will turn a furrow 10 to 12 in (250-300 mm) wide. With trailed implements the discs are mounted on a heavy frame, and the large amount of side-thrust due to the pressure of the soil is carried by the three wheels, the two furrow wheels being inclined in a suitable direction to withstand it. The wheels are often weighted to assist in the penetration of hard land, since the discs themselves have little "suction".

The disc angle (horizontal angle between plane of disc face and direction of travel) is usually just under 45°, while the tilt angle is usually 15 - 23° from the vertical and is easily adjustable. As a general rule, draught is lowest at a disc angle of about 45°, and up to this angle, increasing the angle tends to increase penetration . Increasing the tilt angle from 15° to 25° increase the draught slightly and tends to reduce penetration, but assists in turning the furrow slice effectively. Correct setting of the scraper assists in inverting the furrow and burying rubbish.

Disc ploughs suitable for mounting on the hydraulic lift linkage have now been developed - largely in response to the needs of farmers in countries where mouldboard ploughs are seldom or never employed. Chief advantage of the mounted implement is its maneuverability and ease of transport. A disadvantage is the fact that it has to be made reasonably light to facilitate lifting. Disc ploughs are well adapted to ploughing extremely hard soils. They also deal with certain types of sticky soil better than the mouldboard plough, and will work in long, loose rubbish where no mouldboard plough will run. They are widely used in America. Australia and Africa, but seldom in Britain. They cannot satisfactorily replace the mouldboard plough for ordinary purposes in this country owing to their failure to bury rubbish completely or to cut all the ground. They can, however, be applied to certain special jobs, and are particularly useful for the rapid breaking up of stubbles where there is a large amount of rubbish, as when straw is left on the field by a combine harvester. Moreover, the requirements for weed control are tending to become less stringent with the development of improve herbicides.

'Stump-jump' disc ploughs of Australian origin have been used successfully for very rough work such as preparing land for reseeding where there are tree stumps, tree roots or large rocks to contend with. The stump-jump disc plough will stand up to work that would ruin any mouldboard plough, however strongly constructed.

The 'disc tiller' (British Standard term), 'harrow plough', 'vertical-disc plough' or 'poly-disc' has a number of disc mounted at a uniform spacing sof 8 – 10 in (200 – 250 mm) on a common axle or gang bolt. The disc angle is usually about 40 - 45°, and there is a considerable range in disc sizes. This implement has an action intermediate between that of the true disc plough and the disc harrow. It is commonly employed, with a seed- box attached, for ploughing and seeding in one operation in the drier parts of the Canadian Prairie Provinces; but for British conditions its inability to bury rubbish effectively has hitherto restricted its use to such operations as stubble cleaning.

The general tendency in the Canadian Prairies and similar regions of the United States is towards wider implements and shallower work. Many years ago, in the days of the early settlers, mouldboard ploughs were used . These were succeeded inturn by the disc plough and the disc tiller or 'poly-disc', and the recent development is the 'discer', usually a very wide implement, with moderately small disc mounted in gangs of six and capable of independent vertical movement on the main frame. This implement normally works only about 3 in (75 mm) deep, and usually has a seed-box attached. The power lift raises the disc and shuts of the flow of seed, but does not raise the whole frame of the implement as it does in the case of the disc tiller.

2.2 ADVANTAGES OF DISC PLOUGH

The advantages of disc plough over mouldboard plough are as follows:-

1. There is less wear on the disc than the mouldboard plough share.
2. The length of disc blade is greater than that of mouldboard plough share blade.
3. The disc has self grinding action which saves the whetting and sharpening necessary with plough shares.

4. Less soil stick to the discs than in the case of moulboard ploughs.

2.3 TYPE OF DISC PLOUGHS

2.3.1 **Trailing disc** plough (figure 1) is fitted with bottoms fastened by bolts to the main beam of the frame. A land wheel with mechanical lift is fastened to the rear plough bridge. The furrow and rear wheels are inclined and are fitted on their circumference by means of collars which absorb the landside resistance of the soil. The wheel arrangement, one at the front and two at the rear, in a rather narrow tract - may cause the plough to overturn when turning to the right; therefore the plough must be always turned to the left.

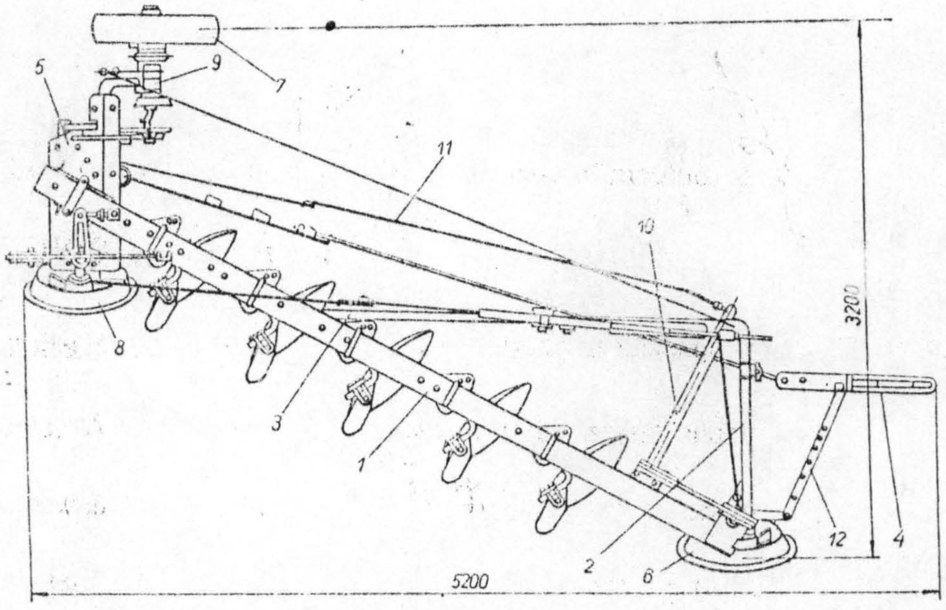


Fig. 1a Trailing disk plow for deep plowing: 1 — main oblique bar; 2 — crossbar; 3 — longitudinal bar; 4 — hitchbar; 5 — rear bridge; 6 — furrow wheel; 7 — land wheel; 8 — rear furrow wheel; 9 — mechanical lift; 10 — lift shaft; 11 — lift link; 12 — control link.

The pull bar is connected with the rear bridge and a link controlling the furrow wheel. The bar is fixed in a sliding manner to the outrigger fastened to the front of the frame.

In the front part of the pull bar, a spring absorber is set up. Disc ploughs are not equipped with automatic cutouts. In order to make it possible to turn furrow and rear wheels, their bowed axles are mounted in the vertical sleeves of the frame. In the upper vertical parts of the axle, rollers are placed through which are drawn ropes connected with the control and lifting mechanisms.

In disc ploughs - by contrast with mould board ploughs - the width of cut can be changed within limits up to 20 percent.

Change of width consists in an appropriate setting of the main bar in relation to the rear bridge or in re-arranging the two rear wheels in relation to this bridge and rearranging the furrow wheel by shortening or elongating the control link. The position of the pull bar must be adjusted

to the new arrangement of the plough. The trailing disc plough is, despite its somewhat heavy construction too light to penetrate easily into firm or sodded soil. To increase the weight of the plough, the rear bridge is loaded with cast iron or concrete dead weights.

2.3.2. **Wheat Land Disc Plough** (Fig. 2) are intended for shallow and medium tillage and differ in design from other trailing disc ploughs. This type of plough is without bottoms, and discs are drawn one after another on a shaft mounted in bearings fastened to the main bar thus giving to the discs a vertical position resulting in considerably inferior quality of tillage to that of ploughs of other types.

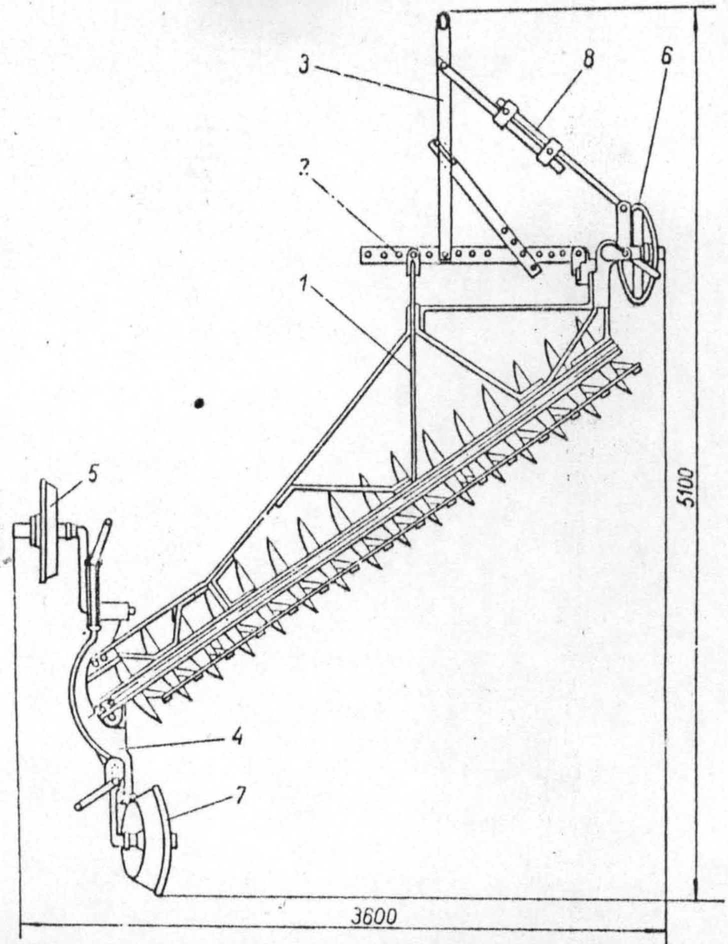
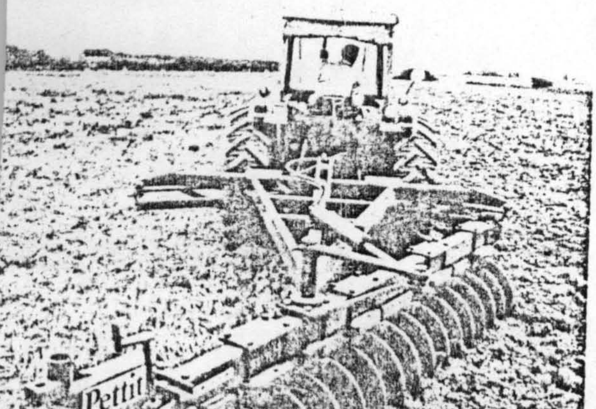


Fig 1b Trailing wheatland disk plow for medium-deep plowing: 1 — frame; 2 — hitchbar; 3 — pull bar; 4 — rear bridge; 5 — land wheel; 6 — furrow wheel; 7 — rear furrow wheel; 8 — control link.



1c Semi-mounted reversible 16-disc cultivator aking stubble. By activating the hydraulic ram the l-bar is swung to left or right round the pivot point, ... running on a curved rail (*Pettit*)

Fig. 2a Mounted disc plough working in hard-baked land (*Ransomes*)

The plough frame is supported by three wheels two of which - the furrow and rear wheels are inclined to counteract the landside resistance, and are torsional to facilitate the turns of the plow. This type of plough may be without hydraulic lift and in this case the controlling spindles fixed to the wheels not only regulate the tillage depth and plough level but are also used to raise the transport position. This type of plough is not raised at turns, since manual lifting would be a long and arduous process. The pull bar is connected with the hitchbar and with the controlling link of the furrow wheel similarly as in disc ploughs equipped with bottoms.

2.3.3. **Mounted disc Ploughs** (fig. 2) are seldom made since they are too light to penetrate into any soil where tillage condition tend to be hard. By contrast with mould board ploughs, mounted disc ploughs are always fitted with a wheel having a coller located behind the last bottom. If the plough is further equipped with a gauge wheel, this is also provided with a coller. In ploughs of this type, pneumatic tires replace steel rims. The angle of setting of all the wheels of the plough can be varied in relation to the main bar, which enables adjustment of the width of tillage.

2.3.4. **Mounted Swivel disc Ploughs** These have bottoms set up rotatably in vertical sleeves. Bottom shanks have at the end arms connected by a common link with a hand lever by means of which discs are turned to one side or the other. A catch released by pressing hand levers enables discs to be set in a required position.

Like other types of mounted ploughs, the swivel plough has in front of the frame a column to which is fastened the upper link and pivots attaching lower links which at the same time may be without control device.

2.3.5 **Balance Disc Plough** Balance disc ploughs differ from mold board ploughs only in their bottoms and in having rear furrow wheels. Balance and swivel disc ploughs are unfit for one direction ploughing on hill sides when their gradient exceed 5° because then, they throw furrow slices upwards in unsatisfactory manner.

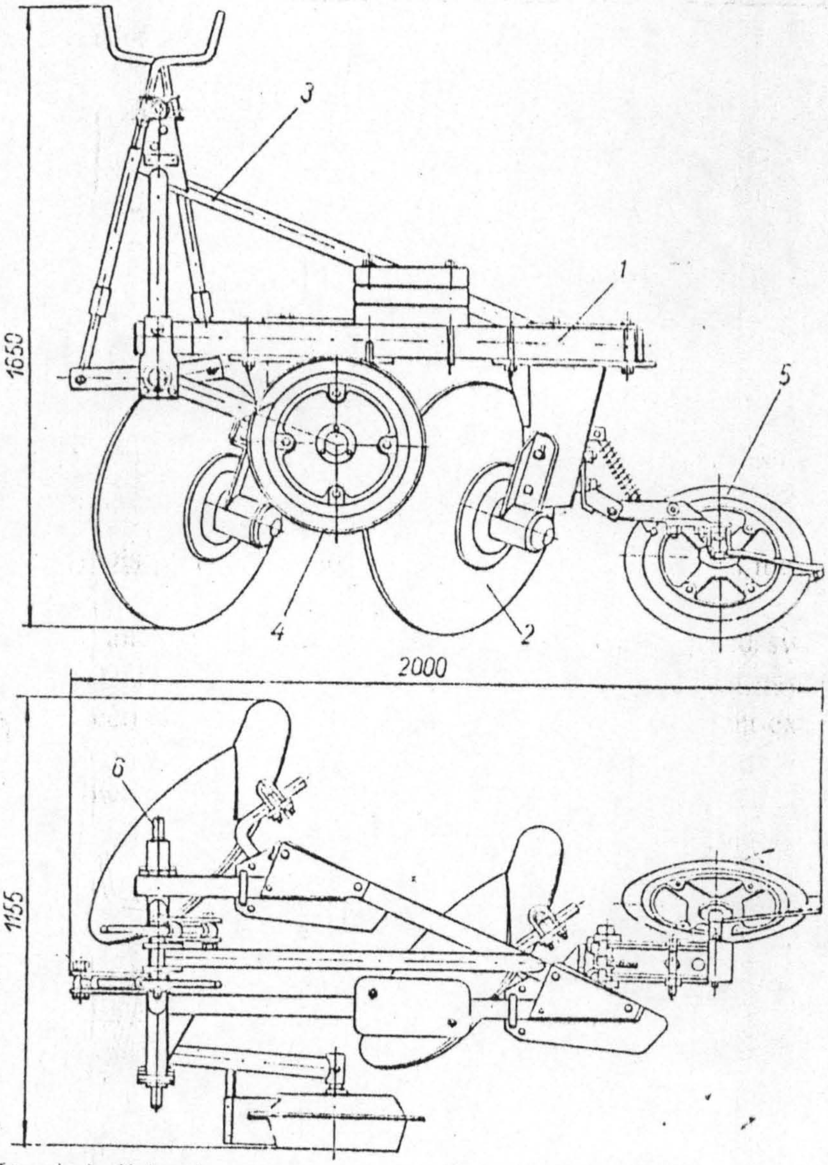


Fig. [illegible] Mounted disk plow: 1 — frame; 2 — disk bottom; 3 — column; 4 — gauge wheel with collar; 5 — rear furrow wheel; 6 — shaft of mounting device.

Fig. 2(b) Mounted Disc Plough

2.4 OBJECTIVE

The objective of this project is to:-

(1) Examine the working condition of used Disc ploughs in order to identify the parts with get damage more frequently and the causes of such damage.

(2) To find means of minimizing or eliminating the problems identified in number 1 above.

(3) To design and construct a model of sleeve bearing which can be used as a substitute to the rolling contact bearing of disc plough being used at present.

2.5 JUSTIFICATION

Disc plough is widely used in many parts of Northern Nigerian because of their suitability to the nature of the soil in this area. Many of these disc ploughs can be seen lying idle because of one problem or another. Therefore, there is a need to survey and examine their working condition in order to ascertain the problems, related to the operation and management of those implements, and how those problems can be tackled. Since no any work has been carried out in this respect I was mandated to investigate and study the causes in order to identify the problems and find solution to them.

2.6 LIMITATION

During the course of this study, I was able to identify the bearing and the hub of the disc plough as the major parts which get damaged more frequently. The causes of damage are numerous – poor maintenance, misuse, soil type and composition etc. in view of this, there is a need to design and construct an alternative bearing and hub which are cheaper and easier to maintain and which can operate better in such difficult conditions like those stated above. Babbit metal is the proposed bearing material and a sleeve bearing is to be used instead of the problem some rolling contract bearing,

However, I encountered many problems for example that of the bearing material (Babbit metal) for which the composing elements were not available locally, foundry materials for moulding and casting of the original bearing and lastly limited financial resources.

In view of this, the study is limited to design of actual bearing and constructing of the models of the bearing and its housing by the use of aluminum alloy.

CHAPTER THREE

MATERIALS AND METHODS

The survey covered 34 private, governmental and Agricultural Development project (ADP) farms in 15 local government areas of Niger State. The areas visited were Shiroro, Kontagora, Mokwa, Bida, Kacha, Edati, Wushishi, Lavun, Chachaga, Bosso, Paikoro, Rafi, Munya, Suleija and Gurara

To accomplish this task, a questionnaire was designed and distributed to the farmers to complete. Information required include plough type/make, age, present working condition, name of damaged parts if any, cause, date and extent of damage, method and cost of obtaining the damaged parts, specification numbers of damaged parts, and the present working condition of each major part (beams discs, bearings, hubs, shafts, furrow wheels, scrapers, bolts, nuts and washers, etc).

For each plough, there are 6 bearings, 3 hubs, 3 discs, 3 shafts, a beam, a furrow wheel, 3 scrapers and sets of bolts, nuts and washers. In the grading of the working condition of these parts, the sets of bearings, hubs, discs, shafts, bolts, nuts and washers and scrapers were considered as units for ease. The information required and the grading system used to assess the working condition of the ploughs and their major parts are explained in the table 1 below:

TABLE 1

1.1 Name of organisation, parastatal or farm..................................

....

1.2 Local Government Area..

....

1.3 Location (Town/Village/Street/Road)...

....

1.4 Number of ploughs available in the organisation, parastatal or farm....

....

....

PART II

In the table below, please fill in the columns for each plough in your organization, parastatal or farm, and assess the working condition of the ploughs and their major parts using the following grading system. 5. Excellent working condition, 4. Very good working condition, 3. Good working condition, 2 Not in working condition. 1. The part is total absent

Using the grading system stated above please assess the working conditions of these parts of the plough. If the part has been replaced within the past one year indicate this by putting an asterix (*) against the grade.

S/No.	Type-make of plough	Age/date of purchase	Present working condition of the plough	Name of damaged part if any	Date of damage	Specification No. of damaged part	Caurses of damage	Extent of damage	Method of obtaining part	Cost of obtaining the damaged part	Beam	Set of bearings	Set of dics	Set of shafts	Set of hubs	Furrow wheel	Set of scrapers	Set of bolts, nuts & washers.

PART III

3.1 Comment:..
....
....
....
....
....

3.2 Name of the officer in charge of the organisation, parastatal or farm.................
....

3.2 Signature of the officer in charge of the organisation, parastatal or farms:.........
....

3.4 Date: ....

CHAPTER FOUR

ANALYSIS OF RESULTS

During the survey many of the disc ploughs encountered were in poor conditions. The pictures (plates 1-5) below show the states in which some used disc ploughs were met. The destruction of the parts seen on the pictures usually started from bearing failure. When damaged bearings can not be replaced, mainly due to their costs, some farmers resort to welding the discs to the hubs. This causes serious wear of the discs cutting surface. The hubs are also damaged by the welding.

Plate 1: MF disc plough in excellent working condition.

Plate 2: MF disc plough in poor working condition. Note the worn out and missing discs. The furrow wheel is absent

Plate 3: MF disc plough in poor working condition. Note a cap of bearing intact into its hub; a disc mounting and set of discs and scrapers are missing.

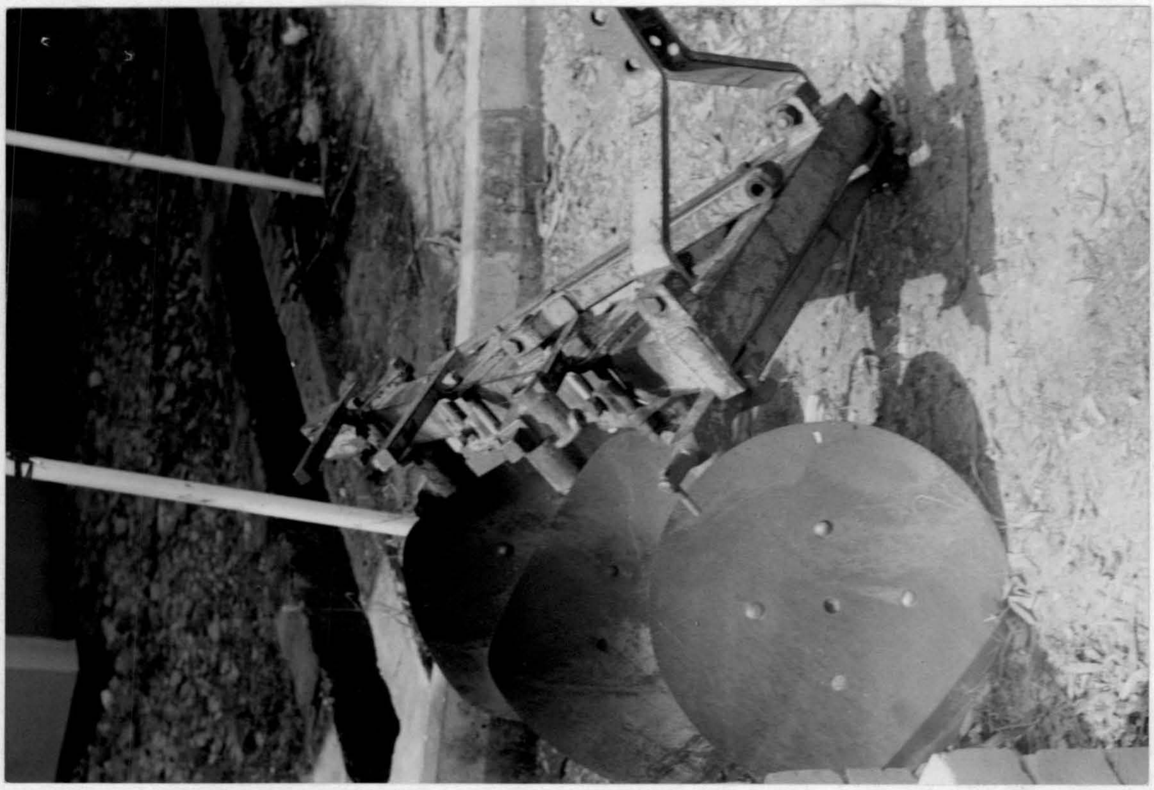


Plate 4: Ford disc plough in poor working condition. Note the worn out discs, missing furrow wheel and scrapers.

Plate 5: Ford disc plough in poor working condition. Note the Worn out discs, missing furrow wheel and scrapers.

Plate 6: Caps of damaged bearings of a disc plough.

4.1 Causes of Bearing Failures

During the course of the survey many causes of bearing failures, attributed to improper lubrication, material fatigue, faulty mounting, improper maintenance or handling and the intrusion of foreign debris into the rolling elements of the bearings were identified as follows:-

1. Lubrication failure, identified by grease appearance, abnormal temperature use, noise, bearing discoloration, and retainer failure, which are caused by dirty or wrong kind of lubrication, or too much or in adequate lubrication.

2. Contamination, identified by scoring, pitting, scratching or rust which are caused by dirty or damp surroundings or abrasive waste materials.

3. Fatigue failure, identified by flaking or spalling of the race ways or noisy running which are caused by normal duty or overload.

4. Brinelling, identified by mounting or radial indentations which are caused by forces incorrectly exerted or radial shock load.

5. False Brinelling, identified by axial or circumferencial indentations which are caused by vibration or static bearing.

6. Thrust failure, identified by counter bored bearing or maximum bearing thrust capacity and caused by improper mounting or misalignment.

7. Misalignment, identified by roller path and retainer which are caused by shaft and housing misalignment or shaft bowing.

8. Cam failure, identified by broken cam, roller path or wobble of bearing which are caused by undersize shafting or outer roller unable to align.

4.2 <u>ANALYSIS</u>

Based on the information required in table 1, the responses from the various farmers were collected and interpreted as shown by the data in appendix 11.at the back of this book.

The working condition of the 114 ploughs and their major parts were analyzed by the use of frequency tables, 4.2.1 Types/Makes of Ploughs

The types/makes of ploughs encountered during the survey is as shown in table 2 below:

Table 2

Number and types of Ploughs encountered

Plough type/Make	Tally	Frequency	Percentage
Fiat	HHI HHI III	13	11.4
Ford	HHI HHI HHI HHI HHI HHI HHI II	37	32.46
John Deere	I	1	0.01
Styre	HHI HHI HHI	15	13.16
M.F	HHI HHI HHI HHI HHI HHI HHI HHI HHI III	48	42.27
Total		114	100

From the data above, it can be observed that the distribution of the ploughs, according to make, in the area covered during the survey is fiat 13(11.4%), Ford 37 (32.46%), John Deree 1(0.01%), Styre 15(13.16%) and M.F 48(42.27%). This result indicates that the majority of the farmers in the area covered have a better taste in M.F. ploughs. They said M.F ploughs are more efficient than the other makes and that their spare parts easier to obtain. This result is interpreted by the pie chart: in fig 3 below.

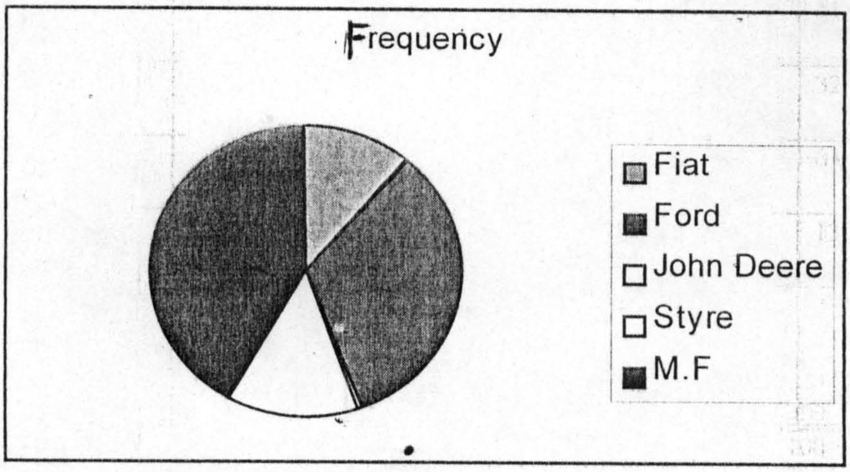


Fig 3 Type/ make of ploughs

4.2.2 **The ages of the ploughs:**

The ages of the ploughs surveyed ranges from 1 to 12 years, with an average age of 4 years. Some of the ploughs are up to six years old but they are in working condition because of the recent rehabilitation carried out by P.T.F as explained above. The frequency distribution of the ages of the 114 ploughs is as shown in table 3 below:

Table 3: **Number of Ploughs and their ages**

AGES (YRS)	TALLY	FREQUENCY	PERCENTAGE
1 - 2	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ II	37	32.46
3 - 4	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	30	26.32
5 - 6	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III	23	20.18
7 - 8	~~IIII~~ ~~IIII~~ III	13	11.4
9 - 10	~~IIII~~ IIII	9	7.9
11 - 12	II	2	1.74
	TOTAL	114	100

From the data given in the table above, it can be observed that majority of ploughs are between 1 to 6 years old. This is represented by the pie chart in fig. 4 below.

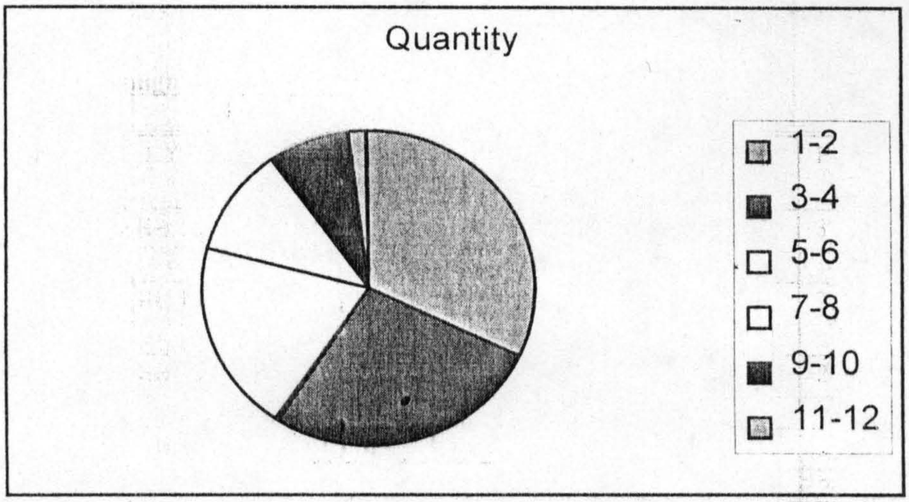


Fig. 4 Ages verses quantity of plough makes

4.2.3 **Working Condition of the ploughs**

From the grading system used in the questionnaire to assess the working condition of the ploughs the following data was obtained, as shown in table 4 below:

Table 4: Working condition Versus number of ploughs

WORKING CONDITION	TALLY	FREQUENCY	PERCENTAGE
1	0	0	0
2	HHI HHI HHI HHI HHI HHI III	33	28.95
3	HHI HHI HHI HHI HHI HHI HHI	35	30.70
4	HHI HHI HHI HHI HHI HHI IIII	34	29.83
5	HHI HHI II	12	10.52
	TOTAL	114	100

From the information in table 4 above, it can be observed that a total of 81 ploughs were in working condition while 33 were not. This represent 71.1% and 28.95% respectively. However, out of these 81 ploughs, 69 of them were newly rehabilitated as mentioned earlier, otherwise, the number of those not in working condition would have been much higher than the recorded 33. Majority of the farmers interviewed stated that working condition of a plough depends on the extent of use, composition of the soil and gravity of maintenance carried out on the plough

4.2.4 Working condition of the beams: The working condition of the beams in the 114 ploughs examined is as shown in table 5:

Table 5: **<u>Number of beams Versus Working Conditions</u>**

WORKING CONDITION OF BEAMS	TALLY	FREQUENCY	PERCENTAGE
1	0	0	0
2	HHI HHI HHI II	17	14.91
3	HHI HHI HHI HHI HHI HHI		30	34.22
4	HHI HHI HHI HHI HHI HHI HHI HHI HHI I	46	40.35
5	HHI HHI II	12	10.52
	TOTAL	114	100

The data in table 5 above showed that 97 out of the 114 beams inspected were in working condition while 17 were not. This represent 85.1% and 14.91% respectively. This result showed that the beam do not give much problem in the operation and management of ploughs.

4.2.5: Working Condition of the set of bearings: The working condition of the set of bearings in the 114 ploughs examined is shown by the data in table 6 below:

Table 6: **<u>Number of bearings Versus working condition</u>**

WORKING CONDITION OF BEARINGS	TALLY	FREQUENCY	%
1	HHI HHI HHI HHI HHI	25	21.93
2	HHI III	8	7.02
3	HHI HHI HHI HHI HHI HHI HHI	35	30.9
4	HHI HHI HHI HHI HHI HHI IIII	34	29.83
5	HHI HHI II	12	10.52
	TOTAL	114	100

The data in table 6 above showed that 25 (21.93%) of the ploughs had their sets of bearings totally absent, and 8(7.02%) ploughs have their bearings intact but they are not in working condition while 81 sets of bearings were in good working condition but 69 of them are newly replaced ones as explained earlier. The result showed that the bearing is the major part which gets damaged more frequently than the other parts of the plough.

4.2..6: Working condition of the hubs: The working condition of the set of hubs is analyzed as shown in table 7 below.

Table 7:**Number of Hubs Versus Working condition**

WORKING CONDITION OF SET OF HUBS	TALLY	FREQUENCY	%
1	0	0	0
2	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III	33	28.95
3	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	35	30.70
4	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII	34	29.83
5	~~IIII~~ ~~IIII~~ II	12	10.52
	TOTAL	114	100

The data in table 7 showed that 33 sets of hubs were not in working condition. This represents 28.95% of the total sets in the 114 ploughs. Also 81 sets were in working condition but 24 of them are newly replaced ones, representing 60.1% and 21.05% respectively.

4.2.7: Working condition of the sets of discs: The working condition of the, sets of discs in the 114 ploughs examined is as shown in table 8 below.

Table 8:**Set of discs Versus working condition**

WORKING CONDITION OF THE SETS OF DISCS	TALLY	FREQUENCY	%
1	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	30	76.32
2	III	3	2.63
3	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	35	30.70
4	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII	34	29.83
5	~~IIII~~ ~~IIII~~ II	12	10.52
	TOTAL	114	100

The data above showed that 30(26.32%) of ploughs had their sets of discs totally absent, 3(2.63%) were not in working condition while 81 set were in working condition but 14(12.28%) of them were newly replaced ones.

4.2.8: Working condition of the set of shafts. The working condition of the sets of shafts in the 114 ploughs examined is tabulated in table 9 below:

Table 9: Sets of Shafts Versus working condition

WORKING CONDITION OF SETS OF SHAFTS	TALLY	FREQUENCY	%
1	HH HH III	18	15.79
2	HH HH HH	15	13.16
3	HH HH HH HH HH HH HH	35	30.70
4	HH HH HH HH HH HH IIII	34	29.83
5	HH HH II	12	10.52
	TOTAL	114	100

From the data shown in the frequency table above, it can be observed that 18(15.79%) set of shafts were totally absent from their respective ploughs, 15(13.16%) were not in working condition while 81(71.1%) are working condition and no replacement at this part was made. This result indicates that the hub is the next, after the bearings, among the major working parts which gets damaged more frequently.

4.2.9: Working condition of the furrow wheels: The working condition of the rear furrow wheel is shown in table 10 below. The function of this wheel is to prevent side to side movements of the plough during operation.

Table 10: Furrow wheels Versus working condition

WORKING CONDITION OF THE FURROW WHEEL	TALLY	FREQUENCY	%
1	HH HH HH HH HH HH II	32	28.09
2	I	1	0.01
3	HH HH HH HH HH HH HH	35	30.70
4	HH HH HH HH HH HH IIII	34	29.83
5	HH HH II	12	10.52
	TOTAL	114	100

This result shows that 32 (28.09%) of the 114 ploughs inspected had their rear furrow wheels totally absent while only 1(0.01%) was not in working condition and 81(71.1%) were in working condition. No replacement was effected on this part. The result proved that the furrow wheel, among the major working parts of the plough, is the one which gives least trouble in the management of ploughs.

4.2.10: Newly replaced parts. The damages of plough parts were caused, mainly by poor maintenance, continued usage, old age and type and composition of the soil. The quantity of each part replaced among the 114 ploughs examined is show in table 11 below.

Table 11:**Number of Newly replaced Parts**

NAME OF PART	TALLY	FREQUENCY	%
Sets of bearings	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII	69	60.53
Set of discs	IIII IIII IIII	14	12.28
Set of hubs	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	24	21.05
Set of shafts	0	0	0
Furrow wheel	0	0	0
Bolts, nuts, Washers	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	70	61.40
	TOTAL	177	

The result above shows that 69 ploughs had their set of bearings replaced, 14 of them had their set of discs replaced, 24 had their sets of hubs replaced while no shaft and furrow wheel were replaced and 70 plough had their sets of bolts, nuts and washers replaced. This showed that a total of 177 sets of parts were replaced among the 114 ploughs inspected. :

4.3 STATISTICAL ANALYSIS AND SUMMATION OF RESULTS

The results of the grading system used in the questionnaire are shown in appendix 111. Based on this information, a statistical analysis was carried out using a simple F. test, in order to find the significant level of the results.

4.3.1 ANALYSIS OF VARIANCE:

All calculations for the analysis of variance is based on appendix 111

The Replications r = 9

The Treatments t = 114

Total Replication n = (r)(t) = 114 x 9

= 1026

i. To compute the variance of each sample:

$$S^2 = \frac{\sum (yij - y_1)^2}{r-1}$$

There are 114 variates.

$$S_1^2 = \frac{(3-3.22)^2 + (4-3.22)^2 + \ldots\ldots + (4-3.22)^2}{9-1}$$

= 1.5556/8

= 0.1945

$$S^2_2 = \frac{(2-178)^2 + (3-1.78)^2 + \ldots\ldots + (2-1.78)^2}{9-1}$$

= 3.5556/8

= 0.4445

$$S^2_3 = \frac{(3-3.11)^2 + (4-3.11)^2 + \ldots\ldots + (3-3.11)^2}{9-1}$$

= 0.1111

$S^2_4 = 0$

$S_5^2 = 0$

$S^2_6 = 0$

$S^2_7 = 0$

$S^2_8 = 0$

$S^2_9 = 0$

$$S^2_{10} = \frac{(2-1.67)^2 + (2-1.67)^2 + \ldots\ldots + (2-1.67)^2}{9-1}$$

= 2.0001/8

= 0.2500

$S^2_{11} = 0$

$$S^2_{12} = \frac{(3-3.11)^2 + (4-3.11)^2 + \ldots\ldots(3-3.11)^2}{9-1}$$

$= 0.8889/8$

$= 0.1111$

$$S^2_{13} = \frac{(2-1.56)^2 + (3-1.56)^2 + \ldots\ldots + (1.56)^2}{9-1}$$

$= 4.2224/8$

$= 0.5278$

$$S^2_{14} = \frac{(2-133)^2 + (2-133)^2 + \ldots\ldots + (1-1.33)^2}{9-1}$$

$= 2.0001/8$

$= 0.2500$

$S^2_{15} = 0$

$S^2_{16} = 0$

$S^2_{17} = 0$

$S^2_{18} = 0$

$S^2_{19} = 0$

$S^2_{20} = 0$

$$S^2_{21} = \frac{(3-3.11)^2 + (3-3.11)^2 + \ldots\ldots + (4-3.11)^2}{9-1}$$

$= 0.8889/8$

$= 0.1111$

$S^2_{22} = 0$

$S^2_{23} = 0$

$$S^2_{24} = \frac{(3-3.22)^2 + (3-3.22)^2 + \ldots\ldots + (4-2.22)^2}{9-1}$$

$= 1.5556/8$

$= 0.1945$

$S^2_{25} = 0.1945$

$S^2_{26} = 0$

$S^2_{27} = 0$

$S^2_{28} = 0$

$S^2_{29} = 0$

$S^2_{30} = 0.2778$

$S^2_{31} = 0$

$S^2_{32} = 0$

$S^2_{33} = 0.5278$

$S^2_{34} = 0.15278$

$S^2_{35} = 0.1945$

$S^2_{36} = 0$

$S^2_{37} = 0.6945$

$S^2_{38} = 0$

$S^2_{39} = 0$

$S^2_{40} = 0$

$S^2_{41} = 0.5278$

$S^2_{42} = 0$

$S^2_{43} = 0$

$S^2_{44} = 0.1111$

$S^2_{45} = 0.2500$

$S^2_{46} = 0$

$S^2_{47} = 0.5000$

$S^2_{48} = 0.5000$

$S^2_{49} = 0$

$S^2_{50} = 0$

$S^2_{51} = 0.2778$

$S^2_{52} = 0$

$S^2_{53} = 0$

$S^2_{54} = 0$

$S^2_{55} = 0.1111$

$S^2_{56} = 0.1945$

$S^2_{57} = 0.5000$

$S^2_{58} = 0.2500$

$S^2_{59} = 0$

$S^2_{60} = 0$

$S^2_{61} = 0$

$S^2_{62} = 0$

$S^2_{63} = 0.2500$

$S^2_{64} = 0.2500$

$S^2_{65} = 0$

$S^2_{66} = 0$

$S^2_{67} = 0.2778$

$S^2_{68} = 0.5000$

$S^2_{69} = 0$

$S^2_{70} = 0$

$S^2_{71} = 0$

$S^2_{72} = 0$

$S^2_{73} = 0$

$S^2_{74} = 0$

$S^2_{75} = 0$

$S^2_{76} = 0.5278$

$S^2_{77} = 0$

$S^2_{78} = 0$

$S^2_{79} = 0.1111$

$S^2_{80} = 0$

$S^2_{81} = 0$

$S^2_{82} = 0$

$S^2_{83} = 0$

$S^2_{84} = 0$

$S^2_{85} = 0.2500$

$S^2_{86} = 0.2500$

$S^2_{87} = 0.2500$

$S^2_{88} = 0$

$S^2_{89} = 0.2778$

$S^2_{90} = 0.2778$

$S^2_{91} = 0.2778$

$S^2_{92} = 0$

$S^2_{93} = 0$

$S^2_{94} = 0.2778$

$S^2_{95} = 0.7500$

$S^2_{96} = 0$

$S^2_{97} = 0.2500$

$S^2_{98} = 0.2778$

$S^2_{99} = 0.6945$

$S^2_{100} = 0$

$S^2_{101} = 0$

$S^2_{102} = 0.6945$

$S^2_{103} = 0$

$S^2_{104} = 0$

$S^2_{105} = 0.6945$

$S^2_{106} = 0$

$S^2_{107} = 0$

$S^2_{108} = 0.1945$

$S^2_{109} = 0$

$S^2_{110} = 0.2778$

$S^2_{111} = 0$

$S^2_{112} = 0$

$S^2_{113} = 0$

$S^2_{114} = 0$

ii. To compute the estimate of variance:

$$S^2_w = \frac{S_1^2 + S^2_2 + \ldots\ldots + S^2_{114}}{114}$$

(0.1945 + 0.4445 +.........+0.2778+

+0+0+0+0)114

= 15.4433/114

= 0.1335

iii. To compute the variance of means

$$S^2_y = \frac{\sum(\bar{y}i - \bar{y})^2}{t-1}$$

$$= \frac{(3.22-3.11)^2 + (1.78-3.11)^2 + \ldots\ldots + (5-3.11)^2}{114-1}$$

= 156.0945/113

= 1.3814

iv. To compute the estimated of variance (S^2b) based on variability within the sample means

$S^2\bar{y} = S^2b/r$

:. $S^2b = r.S^2\bar{y}$

= 9 x 1.3814

= 12.4326

S^2b is based on (114-1) degree of freedom = 113 degrees of freedom.

S^2w is based on (9-1) 114 = 912 d.F

But Total degree of Freedom =((tr)-1)

$= (114x9)-1$

$= 1025$

Treatment d.F = (t-1)

$= 114-1$

$= 113$

Error d.F = Total D.F - Treatment d.F

$= 1025-113$

$= 912$

v. To compute the sum of squares variance

$$SSY = \frac{\sum Y^2 i}{r} - \frac{Y}{n}$$

But $\sum y_i^2 = (29)^2 + (16)^2 + (28)^2 + ... + (45)^2$

$= 99530$

$Y^2 = (3186)^2$

$= 10150596$

Therefore = $SSV = \frac{99530}{9} - \frac{10150596}{114 X 9}$

$= 11058.88889 - 9893.36842$

$= 1165.52$

vi. To compute mean square variates

$$MSV = \frac{SSV}{d.FV} =$$

$$MSV = \frac{1165.5}{113}$$

$= 10.31$

vii. To compute total sum of squares

$$SST = \sum Yij^2 - \frac{Y^2}{n}$$

But $\sum Yij^2 = 3^2 + 4^2 + 3^2 + ... + 5^2 + 5^2 + 5^2$

$= 11376$

Therefore SST $= 11376 - \frac{3186^2}{114x9}$

$= 11376 - 9893.37$

$= 1482.63$

viii Sum of squares Error

SSE = SST - SSV

= 1482.63 - 1165.52

= 1317.11

ix Mean square Error

MSE = SSE/d.F E

= 317.11/912

= 0.35

Grand Mean $= \frac{G}{n}$, where $G = \sum Yi = Y$

Therefore Grand Mean $= \frac{Y}{rt}$

$= \frac{3186}{114x9}$

$= 3.11$

x Co-efficient of variation:

$$C.V = \frac{\sqrt{Error\ M.S}}{Grand\ mean} \times 100$$

$$=\sqrt{\frac{0.35}{3.11}} \times 100$$

$$= 19.02\%$$

$$F \text{ ratio} = \frac{MSV}{MSE}$$

$$= 10.31/0.35$$

$$= 30$$

4.3.2: Table 12: **ANOVA TABLE**

Source of Variation	Degree of Freedom	Sum of squares	Mean Square	Observed F	Tabular F 1%	5%
Total	1025	1482.63				
Variates	113	1165.52	10.31	30	6058**	242*
Error	912	317.11	0.35			

From the results in the ANOVA table shown above, we can conclude that the treatment is highly significant.

CHAPTER FIVE

DESIGN

In this section an attempt was made to design and fabricate (cast) a model of a sleeve bearing which can be use to substitute the rolling contact bearing of the disc plough. The sleeve bearing has the following advantages over the rolling contact bearing:

5.1 Advantage of Sleeve bearing over rolling contact bearing

1. The cost of rolling contact bearings and their provision for mounting is higher than that of plain bearings. In general, plain bearings have low initial cost.
2. Rolling contact bearings can fail without warning, but failure is gradual in plain bearings.
3. The resistance to shock load is lower in rolling contact bearing than in plain ones.
4. Rolling contact bearings have high sensitivity to dirts and other foreign matters than plain bearings because of their rolling elements (rollers, cages balls).
5. The cost of servicing, maintenance and lubrication of rolling contact bearings is higher than that of plain bearings which require little or no service.
6. In plain bearings, greater tolerances can be accommodated between the shaft and the bearing, but this is not possible with rolling contact bearings.
7. No elaborate enclosure is required in plain bearings but rolling contact bearings must be covered completely if they are to render any useful service.

5.2 Load Carrying Capacity

Each application of sleeve bearing deserves a through analysis. The operating environment and temperature, as well as speed and load of the shaft and the life needed from the bearing must be considered. Operating conditions such as vibration, oscillating loads, and loads that vary in direction must be taken into account. In particular, the direction and magnitude of the load will help to determine the correct bearing material as well as the support housing design, the housing material and the location of the lubricant entry.

5.3 Sleeve Bearing Material

A good bearing consists of hard particles to carry the load, embedded in a soft matrix which wears to provide lubrication channels. The white metal have been developed to meet just this requirement, with two different basic metals being used, i.e. lead base and tin base.

(a) Lead base alloy: a typical white metal in this range is 80% lead, 15% antimony 5% tin and the structure consist of hard crystals of tin-antimony compound in relatively soft lead antimony eutectic. These are considered to be inferior to the tin based alloys but are cheaper to produce and find use in low duty or light loads.

(b) Tin base alloys: These are often referred to as Babbitt metals and contain 7-10% antimony. The structure is one of hard crystals of tin antimony compound in a solid solution of antimony in tin. An addition of 3-4% copper improves dispersion throughout the structure. These tin based alloys are use for high duty application.

the average composition of a good white metal is 90% tin: 6% antimony; 4% copper. it is an expensive metal which is sometimes used in high speed bearing such as the big and bearing of internal combustion engines. it has a low melting point and can run even when lubrication fails.

5.4 Babbit Metal

Babbitt metal is a white metal in which part of the expensive tin is replaced by lead. the composition of the Babbitt metal to be used for the construction of this bearing is as follows:

Lead (Pb)	-	80%
Antimony (Sb)	-	12%
Tin (Sn)	-	64%
Arsenic (As)	-	1.6%
Tensile strength	-	10,000 Psi
Elongation	-	2%
BHN	-	22

Babbitt metal has the ability to conform to misalignment, resist corrosion and grit and to operate against steel without scoring.

The housing for the bearing is to be made of cast iron which has the following properties.

Ultimate Strength			Elastic Strength		
Tension	=	138N/mm^2	Tension	=	69N/mm^2
Compression=		655N/mm^2	compression=		172N/mm^2
Shear	=	138N/mm^2			

The aluminium alloy which was used for the casting has the following properties:

Ultimate Strength	Elastic Strength
Tension 103 N/mm^2	Tension = $49N/mm^2$
Compression $83N/mm^2$	Compression = $24N/mm^2$

Aluminium cannot be used for this bearing material because of the following reasons:

(a) Low specific gravity: 2.68 as compared with 7.8 for steel

(b) Relatively low strength; i.e in the soft condition, it has a tensile strength of 6 $tonf/in^2$. However, by the addition of the various elements - copper, magnesium, zinc, silicon, manganese - the strength of 90MPa can be attained. It is therefore suitable for casting and it was used to cast the models of the sleeve bearing and its housing (hub).

5.5 THE DISC BOTTOM

The disc of the disc bottom is bolted to the haft shoulder, mounted in two tapered bearings in the lower part of the frog constituting a bearing housing, or to a flange of a hub mounted by means of two tapered bearings on a shaft integrated with the frog,see fig 3, This kind of connection of the disc with the frog enables the disc to turn freely during tillage. The frog is mostly two part one and enables the inclination of the disc to be changed. The frog is so connected with the frame that within certain limits the disc angle of inclination can be adjusted in the direction of plough movement. The disc bottom has no slade - that is, no land side resistance transmitting element. Most ploughs are provided with adjustable mould boards set up alongside the discs. Their job is to improve the accuracy of turning the furrow slices.

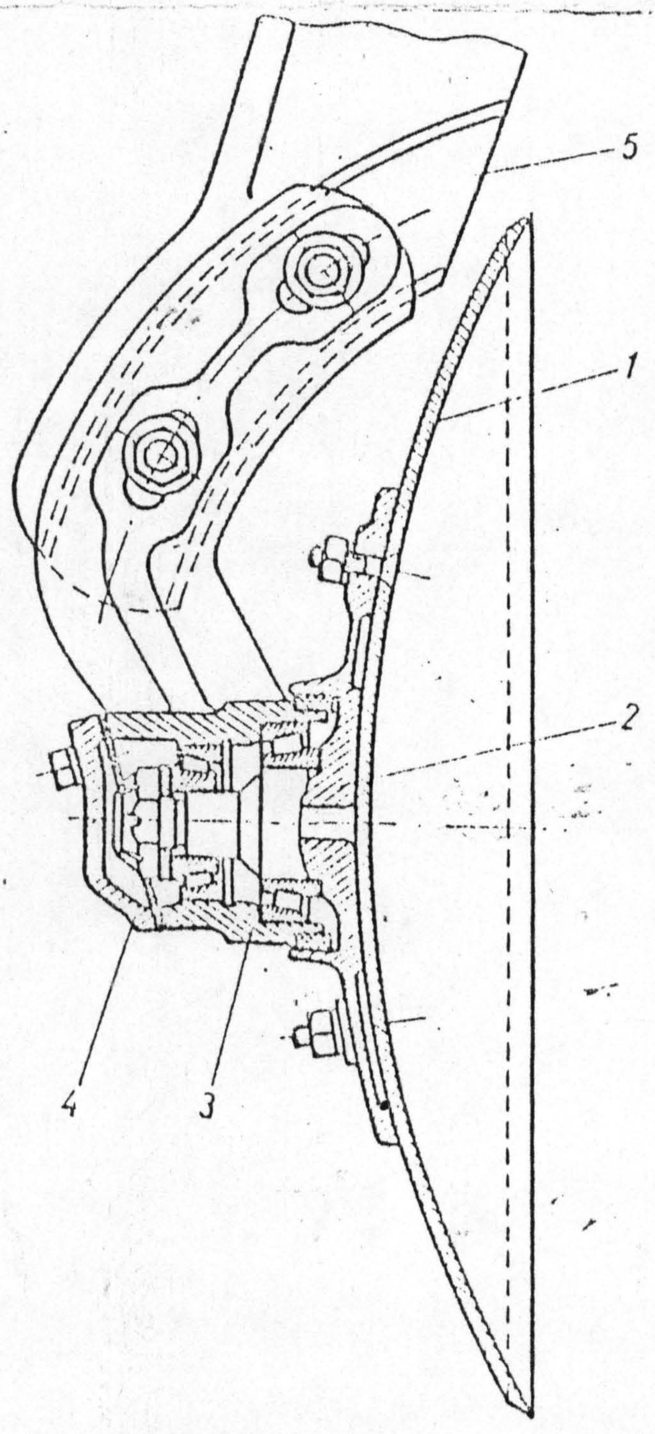


Fig.5 Disk bottom: 1-
Disk; 2 - disk mounting; 3 -
Housing of tapered bearings;
4 - cover; 5 - two-par frog

The shank of the frog of the disc plough bottom is composed of two parts so connected with the head that angles of disc inclination may be regulated.

For example , consider a frog with solid shank, as shown in figure below, whose axes U-U and V-V are parallel to the main axes of the disc. We project the force Kw on the axes of the cross-section.

$$Kwu = Kw \, Sin\,(Ø_o + ß_k)$$

$$Kwv = Kw \, Cos\,(Ø_o + ß_k)$$

$$M'zg = Kwu \, L1 = Kw \, L1 \, Sin\,(Ø_o + ß_k)$$

$$M''zg = KwvL1 = KwL1 \, Cos\,(Ø_o + ß_k)$$

$$Wv = \frac{b\,h^2}{6}$$

$$Wu = \frac{h\,b^2}{6}$$

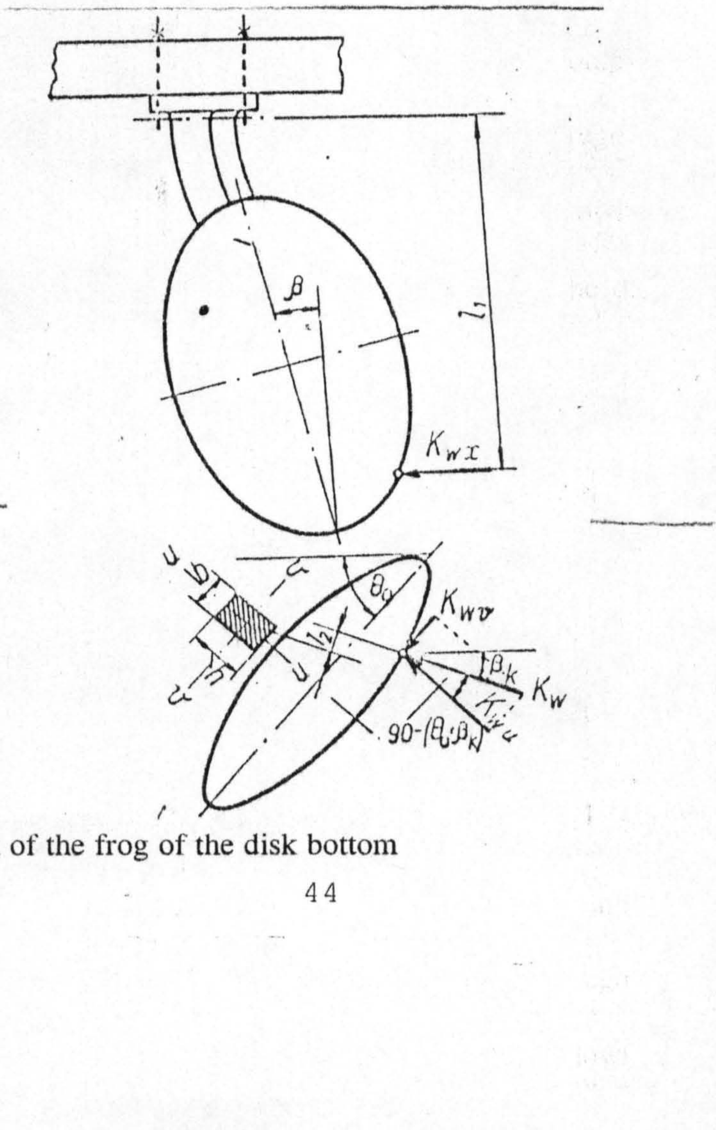


Fig.6 Shank of the frog of the disk bottom

5.6 The frog of the disc bottom

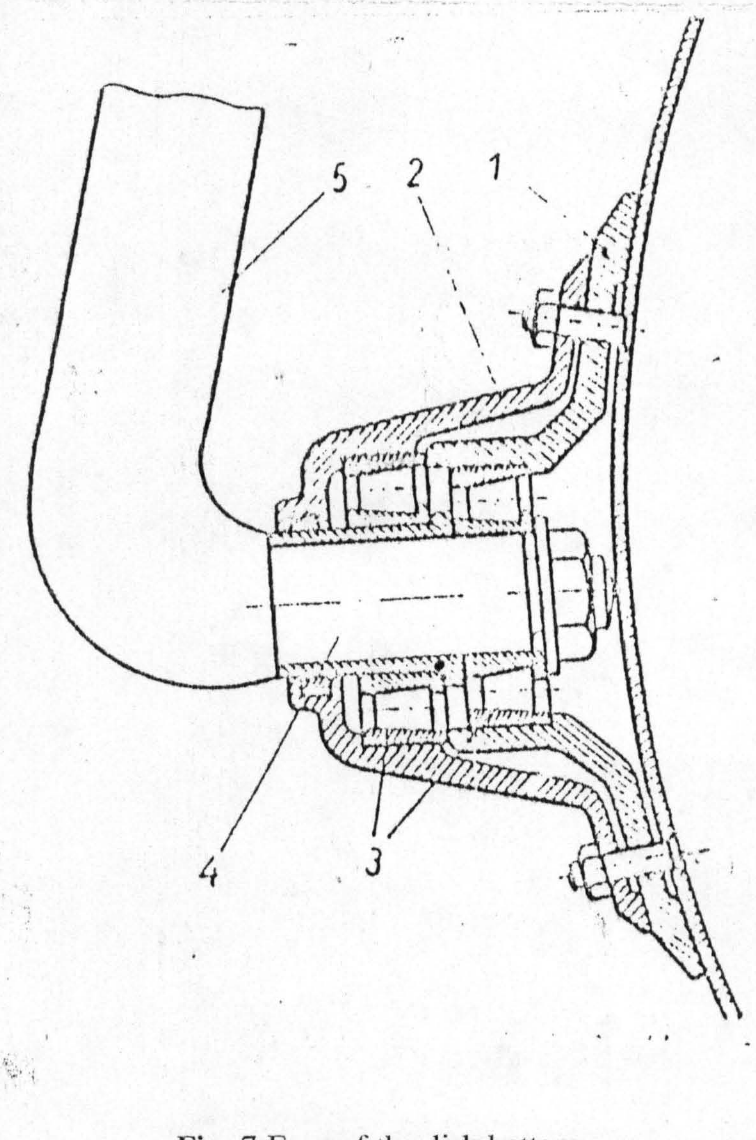


Fig. 7 Frog of the disk bottom
1 -1 holder; 2- cap; 3 - tapper bearings; 4 - shaft; 5 - frog shank

$$\delta' = \frac{M'zg}{IxIv} = \frac{6\ Kwl1\ Sin\,(\theta_o + \beta_k)}{bh^2}$$

$$\delta'' = \frac{M''zg}{IxIu} = \frac{6\ Kwl1\ Cos\ (\theta_o + \beta_k)}{hb^2}$$

The bending stress in the coruer amounts to $\delta = \delta' + \delta''$

Torsional stress can be calcualted from the formula

τ max = (9/2)) (Mskr/bh²) = 9Kwl₂/2bh²

Where h > b.

Reduced stress can be calculated from the formula

$U = \sqrt{\delta^2 max + 4X^2 max}$

5.7 LOAD CARRYING CAPACITY OF THE BABBIT SLEEVE BEARING

Babbit sleeve is usually loaded in accordance with industry standards established by Mechanical Power Transmission Association. The standards are expressed as unit pressure.

$$P = \frac{F}{D \times L}$$

Where P = Unit pressure, Psi

F = Load, lb

D = Shaft diameter, in

L = Sleeve length, in

The shaft of the disc plough mounting is of low velocity and a pressure of 150 Psi is allowable for Babbitt. The shaft velocity is given by

$$V = \frac{\pi D \times N}{12} \text{ (sfm)}$$

Where N is number of revolutions per minute.

Assume P = 150 Psi

D = 3.0in

L = 3.5in

Therefore the force F = PxDxL

= 150 x 3 x 3.5

= 1575 lb (713kg)

The velocity of the shaft:

Assume N = 200 rpm

$$\text{Therefore } V = \frac{\pi\, 3 \times 200}{12}$$

$$= 157 \text{ Sfm}$$

5.8 DETERMINATION OF FORCES ACTING ON THE BEARING

In order to design appropriate bearing, axial forces as well as radial ones must be determined.

It is assumed that the point of application of soil resistance K lies in the middle of the furrow slice on the circumference of the disc (fig 8). Neglecting the soil resistance and the component Kx, we assume that $\beta k = 20^{o}$

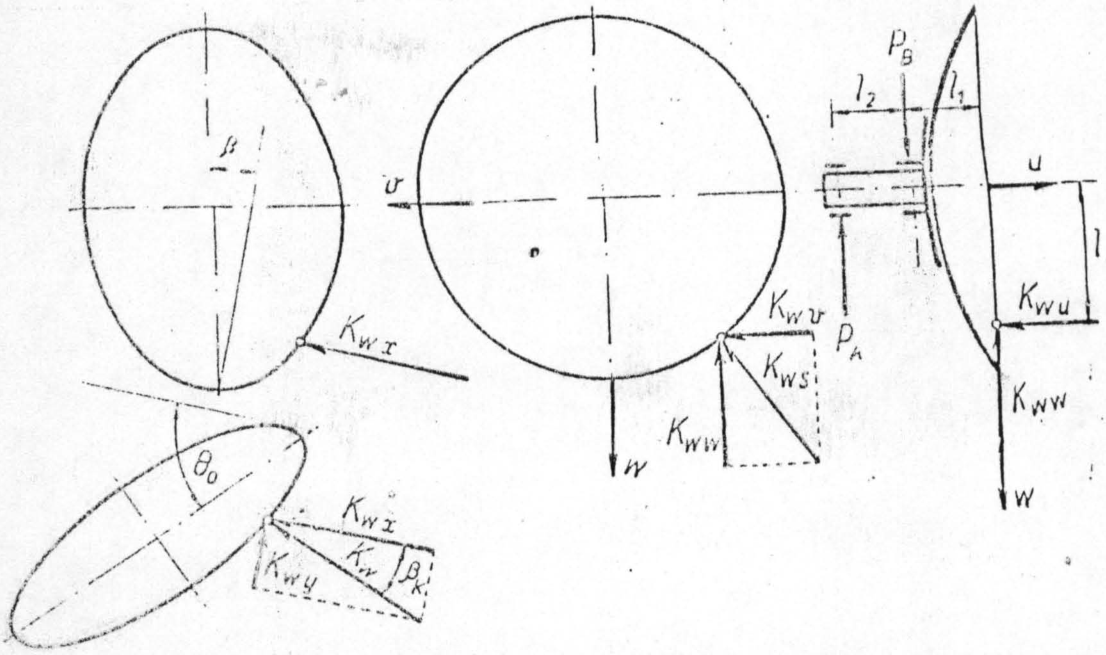


Fig 8 Forces acting on bearings of the frog of a disk bottom

We apply to the same point additional force Kd assuming that in all cases.

$$Kd = K$$

or $$KW = 2K$$

We project the resultant force KW on the plane of the disc on the axes perpendicular to such plane (fig.6) in the system of co-ordinate axes u.w.v.

Particular components in this system amounts to:

$$KWU = KWx \cos \beta_k \sin \theta_0 + KWy \cos \beta_k \cos \theta_0$$

$$KWv = -KWx \cos \theta_0 + Kwy \sin \theta_0$$

$$KWW = -KWx \sin\beta_k \sin \theta_0 - Kwy \sin\beta_k \cos\theta_0$$

The axial force Po acting on the bearing is equal to KWu.

The radial forces can be calculated from the tangential force.

$KWs = \sqrt{K^2Wv + K^2WW}$

$PA = (KWWL_3 - KWSL1)/L2$

$$PB = \frac{KWW\,L3 - KWS\,(L1+L2)}{L2}$$

The axial force KWu is equivalent to the components force of soil resistance on tillage depth made by disc. The specific resistance of soil K are as follows:

Light soil K = 20 - 30Kg/sq. decimeter

Medium firm soil K = 30-50Kg/sq. decimeter

Firm (heavy) soil K = 50 - 70Kg/sq. decimeter

Very heavy soil K > 70Kg/sq. decimeter

5.9 AXIAL FORCES ACTING ON BEARING

Assume: $\beta_k = 20^o$

$\theta_o = 45^o$

K = 400Kg when ploughing in heavy firm soil at a depth of 25cm.

L1 = 200mm = 0.2m

L2 = 85mm = 0.085m

L3 = 210mm = 0.21m

KWx = 300Kg.

KWy = 350Kg

Therefore axial forces are:

$Kwu = Kwx \cos \beta_k \sin\theta_o + KWy \cos \beta_k \cos\theta_o$

$= (300) (\cos 20^o) (\sin 45^0) + (350) (\cos 20^o)(\cos 45^o)$

$= (300) (0.94) (0.71) + (350) (0.94) (0.71)$

$= 200.22 \quad + 233.59$

$= 434Kg$

$Kwv = -KWx \cos\theta_o + KWy \sin\theta_o$

$= (-300)(\cos 45^0) + (350)(\sin 45^o)$

$= (-300)(0.71) + (350) (0.71)$

$= -213 + 248.5$

$= 35.5Kg$

$KWW = -Kwx \sin \beta_k \sin\theta_o - Kwy \sin \beta_k \cos\theta_o$

$= (-300) (\sin 20^0)(\sin 45^0) - 350 \sin(20^0)(\cos 45^0)$

$= (-300)(0.34)(0.71) - (350)(0.34)(0.71)$

$= -72.42 - 84.49$

$= -157Kg$

The axial force Po acting on the bearing is equal to the force KWu = 434Kg.

5.10 RADIAL FORCE ACTING ON THE BEARING

The radial forces are:

$Kws = \sqrt{K^2_{w}v + K^2 ww}$

$= \sqrt{151^2 + (-157)^2} = \sqrt{60050}$

$= 245Kg$

$$PA = \frac{Kww L3 - Kws L1}{L2}$$

$$= \frac{-157 \times 0.21 - 218 \times 0.2}{0.085} =$$

$= -[illegible]00Kg$ (aprox)

$$PB = \frac{KwwL3 - Kws (L1 + L2)}{L2}$$

$$= \frac{(-157 \times 0.21) - \{217\} (0.21 + 0.085\}}{0.085}$$

$$= \{52.97 - 43.57\} / 0.85$$

$= -1144Kg.$ (aprox)

5.11 DESIGN NOTATION

c = specific heat capacity of lubricant Btu/lb/^{0}F

Cd = diametetral clearance, in

Cn = bearing capacity number

d = journal diameter, in

e = eccentricity, in

ho = minimum film thickness, inc.

K = constants (k=1 for single oil hole and 2 for central groove)

l = bearing length for a central oil groove, in

L = actual length of bearing, in

m = clearance modulus

N = rpm

Pb = unit load, Psi

Ps = oil supply pressure, Psi

Pf = frictional horse power

P' = bearing pressure parameter

q = flow factor

Q1 = hydrodynamic flow, gpm

Q2 = pressure flow, gpm

Q = total flow, gpm

Qnew = new total flow, gpm

QR = total flow required, gpm

r = journal radius, in

Dt = actual temperature rise in oil in bearing, ^{0}F

Dta = assumed temperature rise in oil in bearing, ^{0}F

Dtnew = new assumed temperature rise of oil in bearing, ^{0}F

tb = bearing operating temperature

tin = oil inlet temperature, ^{0}F

Tf = frictional torque, in -16/in

T = Torque parameter

W = load, lb
X = factor

Z = viscosity, centipoises

$\prec$ = eccentricity ratio - ratio of eccentricity to radial clearance
= oil density, lb/in^3

5.12 **DESIGN**

Diameter of bearing = 3in (7.4cm)

Journal diameter = 2.9598 in (7.3995 cm)

Load = 959.14 1b (434Kg)

Length of bearing = 3.5in (8.6cm)

Number revolutions per minute (r.p.m.) = 200

Oil supply: SAE 30 at 25^0c (77^0F) and at a pressure of 11 $1b/in^2$ ($24Kg/CM^2$

Figures 9 to 12 show the drawings of the sleeve bearing.

The operating characteristics of this bearing as a function of diametral clearance has to be determined: The problem is stated below:

A full journal bearing 3in diameter and 3.5in long is to carry a load of 959.141b (434Kg) at 200rpm using SAE 30 oil supplied at 25^0 C (77^0F) through a single oil hole at $11lb/in^2$ ($24Kg/cm^2$).

The operating characteristics of the bearing as a function of diametral clearance is determined as follows:

1. Diameter of bearing = 3in (7.4cm)
2. Length of bearing = 3.5in (8.6cm)
3. Bearing pressure:

$$Pb = \frac{W}{Kld} = \frac{959.14}{1x3.5x2.9598}$$

$$= 92.59lb/in^2 \ (41.8957Kg/cm^2)$$

4. Diametral clearance Cd is assumed to be 0.002in for the first calculation

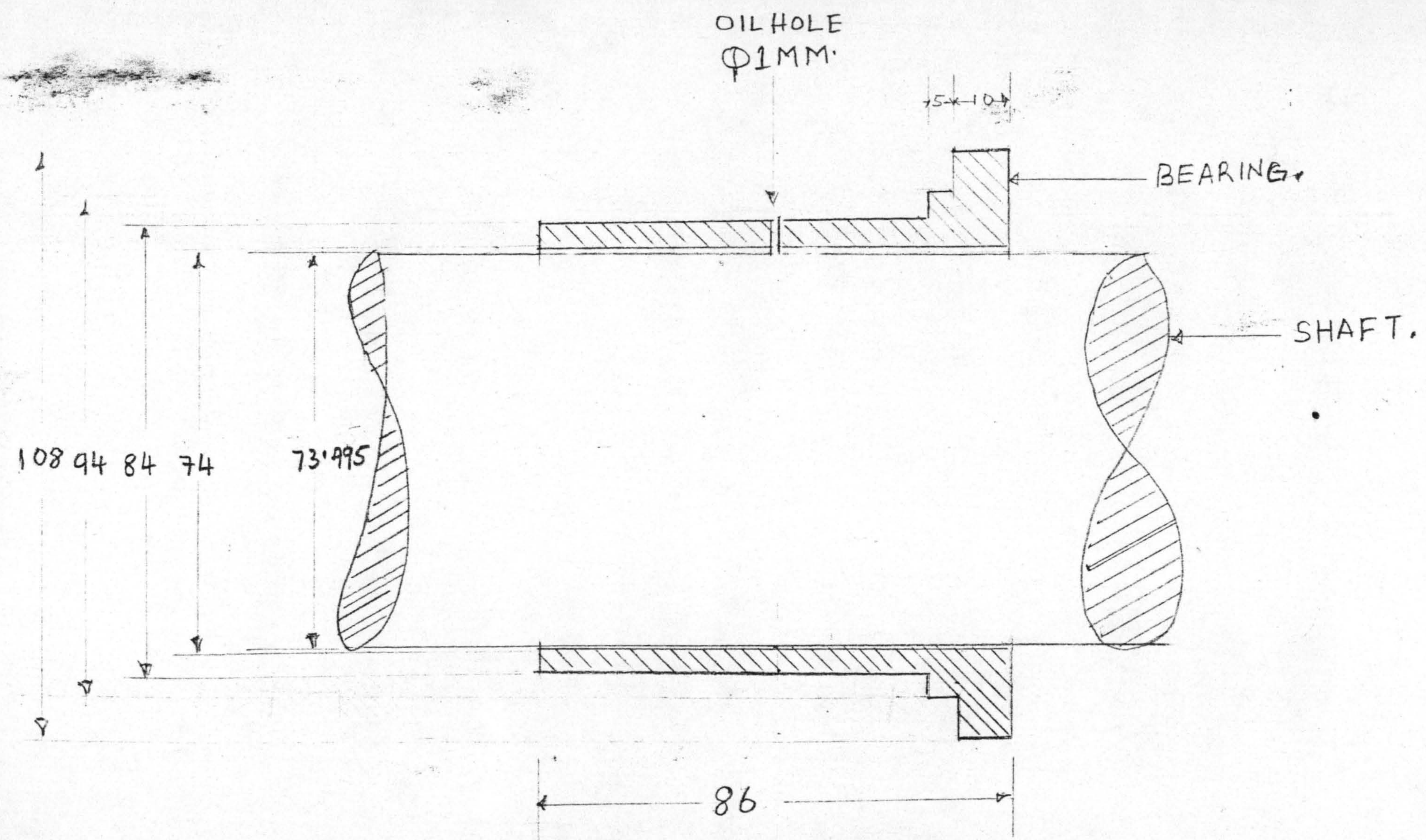


FIG 9. SLEEVE BEARING.
SCALE: 1:1 DIM. IN MM.

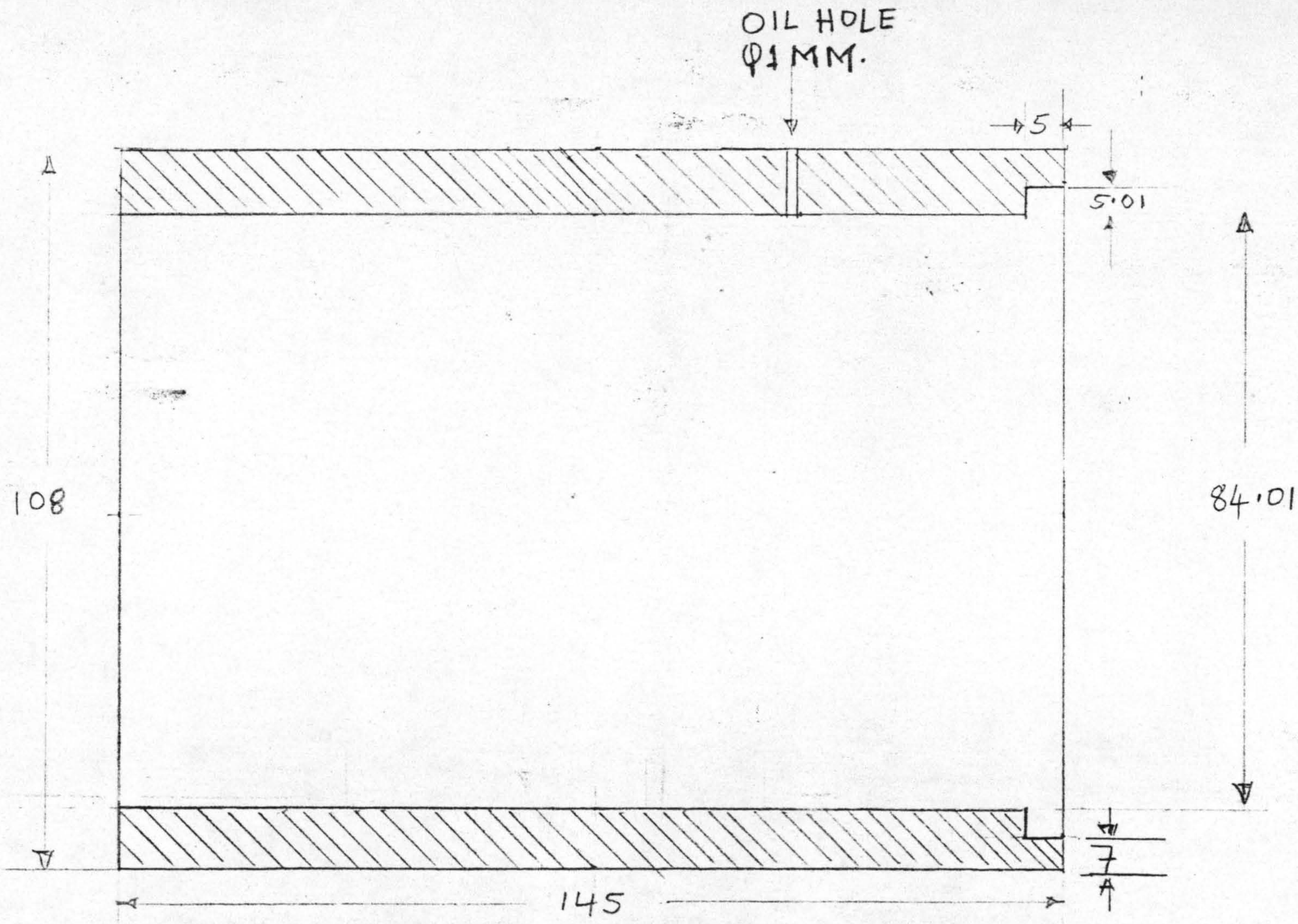


FIG. 10. FROG OR BEARING HOUSING.
SCALE: 1:1. DIM. IN MM

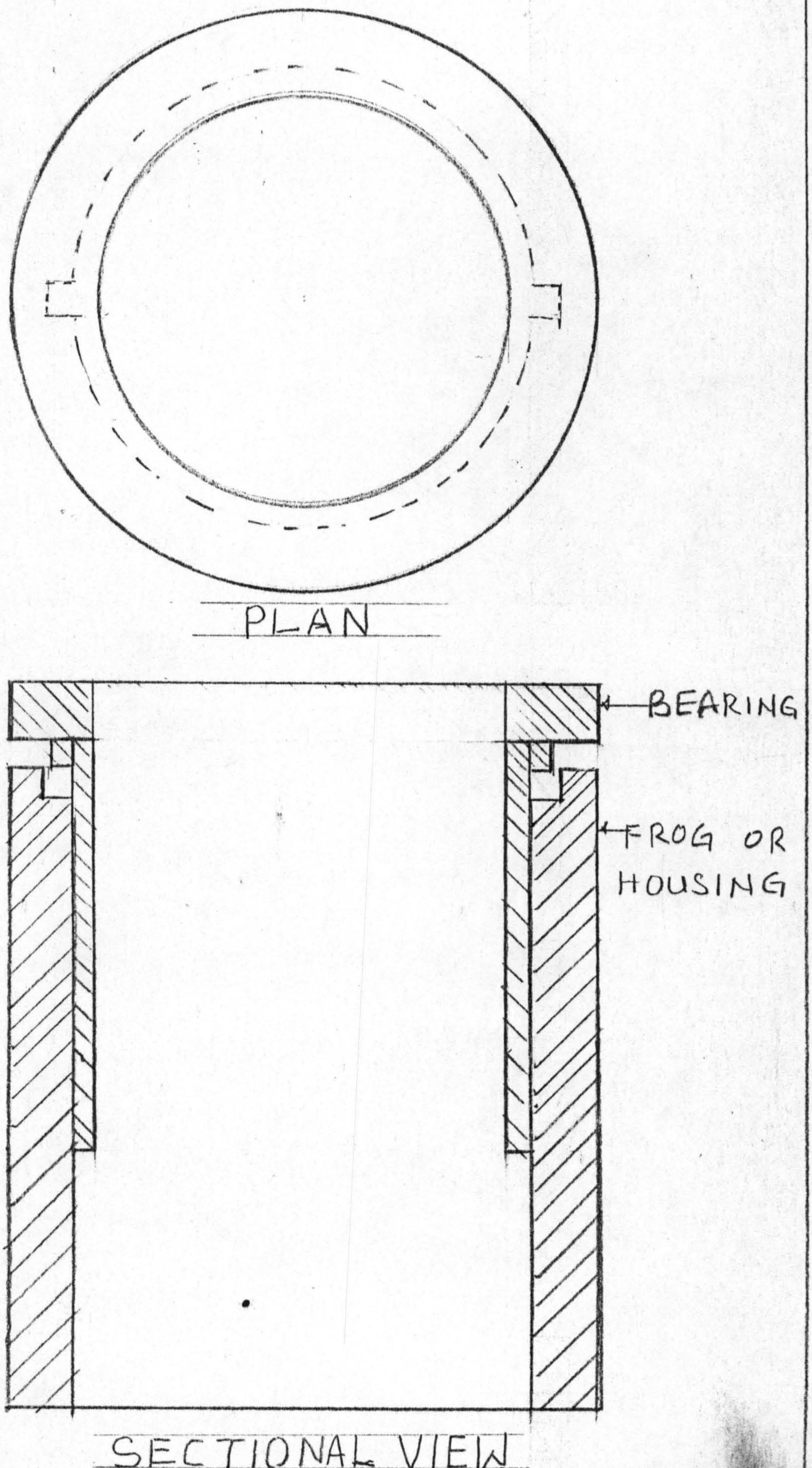


FIG II THE BEARING AND THE FROG

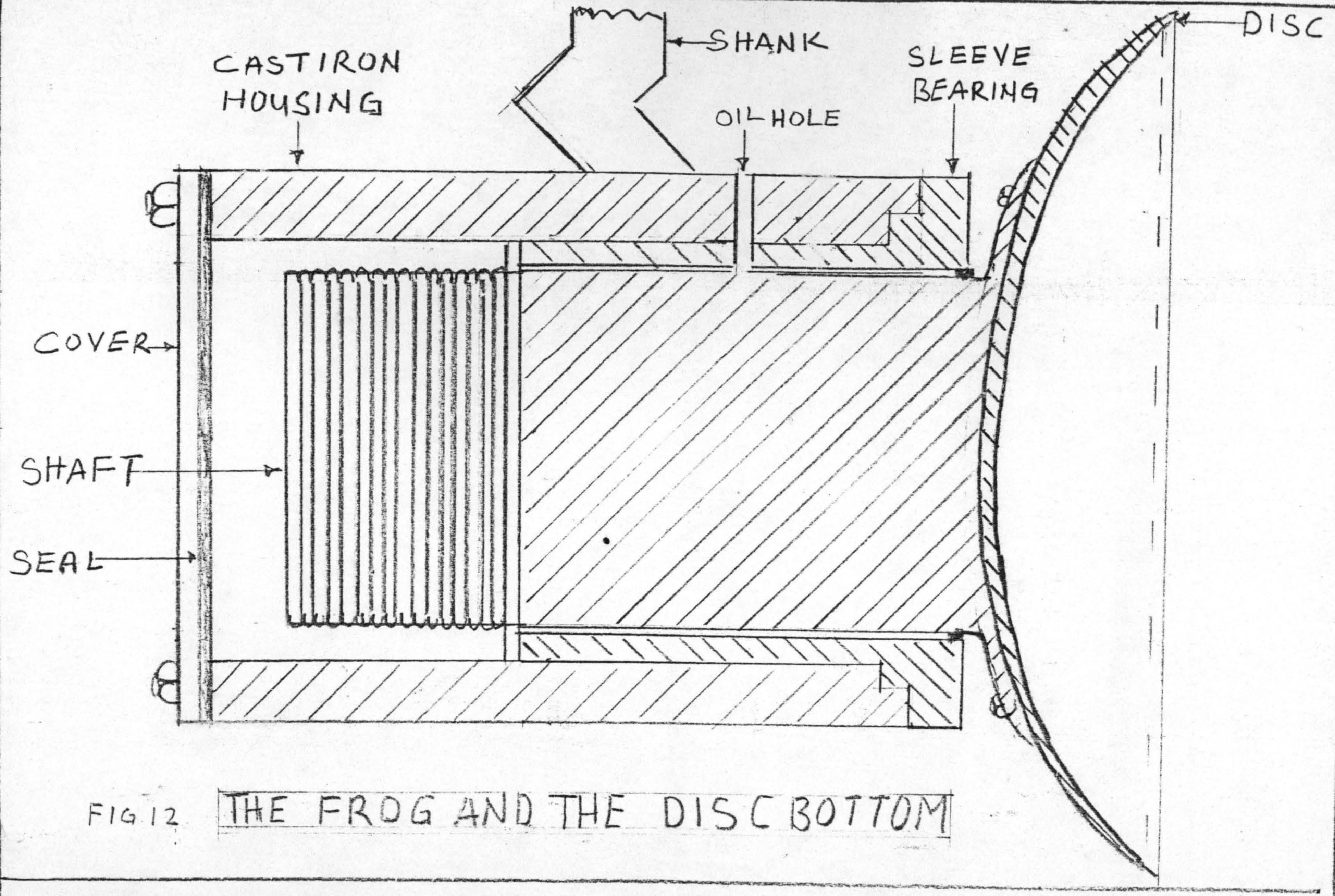


FIG 12 THE FROG AND THE DISC BOTTOM

5. Clearance modulus

$$M = \frac{Cd}{L} = \frac{0.002}{3.5}$$

$$= 0.0006in\ (0.00147cm)$$

6. Length to diameter ratio

$$l/d = \frac{3.5}{3}$$

$$= 1.2$$

7. Assumed operating temperature = 95^{0}F (35^{0}C) and the rise in temperature Dta = 95-77 = 18^{0}F (10^{0}C) and Dtg = Dtin + Dta = 77 + 18 = 95" F

8. Viscosity of lubricant: Assume Z = 15.5 centipoises

9. Bearing pressure parameter

$$P' = \frac{6.9(1000m)^2\ Pb}{ZN}$$

$$= \frac{6.9(1000x0.0006)^2\ x\ 92.59}{15.5\ x\ 200}$$

$$= 0.0742$$

10. Eccentricity ratio: Assume $\frac{1}{(1-\epsilon)} = 6.8$ and $\epsilon = 0.85$

11. Torque parameter: Take T' = 1.46

12. Frictional torque

$$Tf = \frac{T'r^2\ ZN}{6900\ (1000m)}$$

$$= \frac{(1.46)\ (1.4799)^2\ \ (15.5)\ (200)}{6900\ (1000\ x\ 0.0006)}$$

$$= 2.394\ \text{In - lb/in}$$

13. Frictional horse power

$$Pf = \frac{KTNL}{63000}$$

$$= \frac{1 \times 2.394 \times 2000 \times 3.5}{63000}$$

$$= 0.0266hp$$

14. Factor X: Take X = 13 (aprox)

15. Total flow of lubricant

$$Qp = \frac{X\ (Pf)}{Dta}$$

$$= \frac{(13)\ (0.0266)}{18}$$

$$= 0.0192gpm$$

16. Bearing capacity number

$$Cn = \frac{(l/d)^2}{60P'}$$

$$= \frac{(3.5)^2}{(2.9589)^2 (60)\ (0.0742}$$

$$= 0.314$$

17. Flow factor: Assume q = 1.43

18. Actual hydrodynamic flow of lubricant

$$Q1 = \frac{NL\ Cd\ q\ d}{294}$$

$$Q1 = \frac{(200)(3.5)(0.002)(1.43)(3)}{294}$$

$$= 0.0202gpm$$

19. Actual pressure flow of lubricant

$$Q^2 = \frac{K\ Pb\ Cd^2\ (1+1.5e^2)}{ZL}$$

$$= \frac{(1)\ (92.59)\ (0.002)^2\ (1+1.5(0.85)^2)}{15..5 \times 3..5}$$

$= 0.00002$ gpm

20. Actual total flow of lubricant

$Q = Q1 + Q2$

$= 0.0202 + 0.00002$

$= 0.02022$gpm

21. Actual bearing temperature rise

$$Dt = X \frac{(Pf)}{Q}$$

$$= \frac{13(\ 0.0266)}{0.02022}$$

$= 17.10^oF$

22. Comparison of actual and assumed temperature rise: Dt and Dta are within 5^0F, i.e they do not differ by more than 5^0F, i.e Dta = 18' F (10oc), Dt = 17.1^oF hence the bearing will not fail

23. Minimum film thickness

$$ho = \frac{Cd\ (1-\epsilon)}{2}$$

$$= \frac{0.002\ (1-0.85)}{2}$$

$= 0.00015$in

5.13 **CONSTRUCTION OF THE MODEL OF THE SLEEVE BEARING**

A solid cylindrical wood 120mm diameter and 500mm long was obtained from the forest and dried. This wood was used to produce the pattern of the bearing and its housing.

5.13.1 **THE PATTERN OF THE BEARING HOUSING**

The solid cylindrical wood was machined to produce a hollow cylinder with the following dimensions:

Length = 145mm

External diameter = 108mm

Internal diameter = 78.01mm

This pattern is shown in figure.14

5.13.2 **THE PATTERN OF THE SLEEVE BEARING**

The solid wood was machined to produce the pattern of the sleeve with the following dimensions:

Outer most diameter = 108mm

External diameter = 78mm

Internal diameter = 67.01mm

The diameter of the shaft of the disc is 67mm.

Plate7, The patterns of the sleeve bearing 1 Housing; 2 Bearing.

5.14 CASTING OF THE BEARING

When the patterns were completed as shown above, they were taken to the foundry for casting.

I have no materials and resources to make the Babbitt sleeve and the cast iron housing, so I use aluminum to cast the models.

5.14 PROCEDURE

Using naturally bonded earth, the patterns were used to make the moulds of the two components, using molding boxes. Aluminium scraps were obtained and melted in a furnace. The molten metal was poured into the moulds to produce the cast models as shown on plate 8.

Plate 8. The models of the sleeve bearings and its housing.

1- Housing; 2 - Bearing; 3 - Alternative bearing; 4 - Cover.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The deterioration of disc ploughs and their parts depend on age intensity of use (upto 700 hours per year) the type and composition of the soil of particular areas where the ploughs are used the gravity of maintenance and quality of spare parts used.

In stony soil containing large quantities of stones for example mountain soil specific resistance of the soil is high, that is tillage resistance is high. In very heavy soil (i.e. soil containing more than 50% clay) tillage resistance is very high. These types of soils causes faster deterioration of disc plough companents than in upland sandy loam soil which is less harsh and friable because the tillage resistance here is low.

The beams of the disc ploughs hardly get damage and they do not constitute a problem in the management of ploughs.

The bearing is the first major part of the disc plough to get damage. This was accepted by all the farmers interviewed. However new sets of bearings if properly maintained, can last up a season or more depending on the type of soil in the areas where the plough is used.

For any machinery to render satisfactory service for longer times the manual for maintenance and servicing which was provided by the manufacturer must be strictly adhered to .

The rate of wear within the bearings and other components parts of the plough is non uniform. It is advisable to change (replace) the sets of bearings disc etc. at a time. The cost per set of two bearings with specification numbers K3782 and K3984 for MF plough is up to N2500.00

The method of welding the disc mounting to the hub used by some farmers who can not afford to replace the sets of damaged bearing constituted to destruction of other plough components like hubs and disc thus raising the cost of maintenance. The method must be stopped because it is an abuse to the impements.

The bearings in all the ploughs examined are tapered rollers types and their sizes varies depending on makes of the ploughs.

The hub is the next major part after the bearing that gets damaged more frequently and this damage result from failure to replace damaged bearings in time. The cost per hub is N5000.00 the dust proof (cover) N1000.00 and the seal N50.00

The sets of disc can last for 3 years or more before they require replacement except in cases where they broke due to the failure of hydraulic system when the plough suddenly falls and hits the ground surface especially when driving on stony areas or a tarred road. the cost per one disc N5000.00 to N6000.00 depening on price fluction in the markets.

The sets of shaft do not pose much problems in the management of ploughs. However old age misuse improper lubrication of bearing, poor maintenance and failing to replace damaged bearings in time can cause the shafts to wear. The cost per shaft is N7000.00 to N8000.00. At times the threaded portion of the shafts wears out and have to be threaded again using different gauge of tap and dice. The bearings, the shafts and the hubs require regular greasing through the grease nipples provided but many formers do not pay attention to this due to carelessness or lack of enough education on the principles of operation and maintenance of farm machinery. The cost of one tin of grease is N200.00

The furrow wheel rarely gets damage and most of the farmers met do not complain about it, but the spring of the wheel can become weak and its bearing can wear due to improper maintenance misuse and old age as well, but it can last for up to 5 or more years without getting damaged.

Among the 114 ploughs examined the set of bearings in 69 ploughs were replaced within the past one year and this represents 60 53% of the total sets examined. 24 sets of hubs were newly replaced ones representing 21.05% of the total sets inspected. 14 sets of discs were newly replaced ones representing 12.28%. with this we can conclude that the bearings and the hubs are the major parts of the disc plough that get damage more frequently as a result of improper maintenance, misuse, lack of enlightement on care of farm machinery on the parts of the operators, type and composition of the soil and old age as well.

6.2 **RECOMMENDATION**

1. Never allow foreign materials to get into the rolling elements (cages rollers) of the bearing. This causes deterioration of the lubrication substance inside the bearing, resulting in excessive wear, pitting, seizure and subsequent failure of the bearing.

2. Never leave the bearing exposed. Always remember to couple back the dust conver and seals of the bearings after any servicing replacement and or repairs.

3. Grease the bearings, through the nipples provided as recommended by the manufactures. Grease the bearings after every 30 operating hours. Inspect nipples at intervals to clear blockages. The nipples may be covered with rubber or cloth to prevent foreign particles to get into the holes of the nipples to cause blockages.

4. The plough should not be used in areas where large stones are prevailing for example mountain soils but if this could not be avoided, the implement should be raised up when ever large obstructions (stones, root, stumps etc) are encountered, to avoid damages to the bearing and other working components of the plough.

5. Avoid welding the discs to the hubs as practiced by some farmers when they can not afford to replaced the sets of damaged bearings. This method destroys the hubs and the discs thus causing additional expenses. When discs are welded to the hubs such that they cannot rotate, there will be a drastic wear on the portion of the circumference of the disc which cuts the soil, and in addition to this, very poor quality work will be produced since the soil will be cut without being turned and inverted.

6. The hydraulic system of the tractor should always be kept in good working condition to avoid the implement from falling to the ground during operation or transportation on hard groud. when hydraulic pump fails, the plough suddently hits the ground thus damaging the bearing, the discs and other components of the plough.

7. Avoid using incorrect parts or parts of inferior qualities. Since many farmers complained on this problem of poor quality parts, the bearing manufacturers in Nigeria like the machine Tool company of Nigeria at Osogbo in Osun state and the Defence Industries Co-operation of Nigeria (DICON) at Kaduna should improve the qualities of the bearings and other parts of the plough they produce by

increasing their strengths to surface the present ones and to match the imported bearings.

8. Ensure that the check chains at the lower links of the tractor are always in position and have equal slackness to adequately assist the thrust wheel in controlling the left to right movement of the plough which, if not checked can cause damaged to the bearings and other working components of the disc plough

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APPENDIX I

SURVEY OF THE WORKING CONDITION OF USED DISC PLOUGHS IN SOME SELECTED LOCAL GOVERNMENT AREAS OF NIGER STATE

Introduction:

The aim of this survey is to find out the working conditions of used disc ploughs in order to identify the parts which get damaged more frequently and the causes of damage. This is carried out with the object of finding means of minimizing or eliminating the problem

QUESTIONNAIRE

PART I

1:1 Name of organization, parastatal or farm...

....

1:2 Local Government Area:...

....

1:3 Location (Town/Village/Street/Road)..

....

1:4 Number of ploughs available in the organization, parastatal or farm..............

....

PART II

In the table below, please fill in the columns for each plough in your organization, parastatal or farm, and asses the working condition of the ploughs and their major parts using the following grading system: 5. Excellent working condition, 4. Very good working condition, 3. Good working condition, 2. Not in working condition
1. The part is totally absent

S/NO.	TYPE-MAKE OF PLOUGH	AGE/DATE OF PURCHASE	PRESENT WORKING CONDITION OF THE PLOUGH	NAME OF DAMAGED PART IF ANY	DATE OF DAMAGE	SPECIFICATION No. OF DAMAGED PART	CAURSES OF DAMAGE	EXTENT OF DAMAGE	METHOD OF OBTAINING THE DAMAGED PART	COST OF OBTAINING THE DAMAGED PART

Using the grading system stated above please assess the working conditions of these parts of the plough.. If the part has been replaced within the past one year indicate this by putting an asterix (*) against the grade.

BEAM	SET OF BEARINGS	SET OF DISCS	SET OF SHAFTS	SET OF HUBS	FURROW WHEEL	SET OF SCAPERS SCRAPERS	SET OF BOLTS, NUTS AND WASHERS

PART III

3.1 Comment ....

....

....

....

....

3:2. Name of the officer in charge of the organization, parastatal or farm: ....

....

3:3 Signature of the officer in charge of the organization, parastatal or farm:

....

3:4 Date:..

			WORKING CONDITION									
S/NO	PLOUGH TYPE MAKE	AGE (YEARS)	THE PLOUGH	BEAM	SET OF BEARINGS	HUB	SET OF DISCS	REAR THRUST WHEEL	LINKAGE POINTS	SCRAPERS	BOLTS NUTS WASHERS	SET OF SHAFTS
1	FLAT	3	3	4	3	3	3	3	3	3	4	3
2	"	7	2	3	1	2	2	1	2	1	2	2
3	"	3	3	4	3	3	3	3	3	3	3	3
4	"	4	3	3	3	3	3	3	3	3	3	3
5	"	1	5	5	5	5	5	5	5	5	5	5
6	"	2	5	5	5	5	5	5	5	5	5	5
7	"	4	3	3	3	3	3	3	3	3	3	3
8	"	1	5	5	5	5	5	5	5	5	5	5
9	"	6	3	3	3	3	3	3	3	3	3	3
10	"	8	2	2	1	2	2	1	2	1	2	2
11	"	2	4	4	4	4	4	4	4	4	4	4
12	"	3	3	4	3	3	3	3	3	3	3	3
13	"	7	2	3	1	2	1	1	2	1	1	2
14	FORD	10	2	2	1	2	1	1	2	1	1	1
15	"	6	3	3	3	3	3	3	3	3	3	3
16	"	1	5	5	5	5	5	5	5	5	5	5
17	"	2	5	5	5	5	5	5	5	5	5	5
18	"	1	5	5	5	5	5	5	5	5	5	5
19	"	2	4	4	4	4	4	4	4	4	4	4
20	"	6	3	3	3	3	3	3	3	3	3	3
21	"	3	3	4	3	3	3	3	3	3	3	3
22	"	2	4	4	4	4	4	4	4	4	4	4
23	"	2	4	4	4	4	4	4	4	4	4	4
24	"	3	3	4	3	3	3	3	3	3	4	3
25	"	3	3	4	3	3	3	3	3	3	4	3
26	"	3	4	4	4	4	4	4	4	4	4	4
27	"	6	3	3	3	3	3	3	3	3	3	3
28	"	2	4	4	4	4	4	4	4	4	4	4
29	"	2	4	4	4	4	4	4	4	4	4	4
30	"	9	2	2	1	2	1	1	2	1	2	1

66	"	5	3	3	3	3	3	3	3	3	3	3
67	M.F	9	2	2	1	2	1	1	2	1	1	1
68	"	6	2	3	2	2	1	1	3	1	1	2
69	"	2	4	4	4	4	4	4	4	4	4	4
70	"	2	4	4	4	4	4	4	4	4	4	4
71	"	3	4	4	4	4	4	4	4	4	4	4
72	"	2	4	4	4	4	4	4	4	4	4	4
73	"	2	4	4	4	4	4	4	4	4	4	4
74	"	2	4	4	4	4	4	4	4	4	4	4
75	"	1	5	5	5	5	5	5	5	5	5	5
76	"	6	2	3	1	2	1	1	3	1	1	2
77	"	2	4	4	4	4	4	4	4	4	4	4
78	"	2	4	4	4	4	4	4	4	4	4	4
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84	"	4	3	3	3	3	3	3	3	3	3	3
85	"	9	2	2	1	2	1	1	2	1	1	1
86	"	8	2	2	1	2	1	1	2	1	1	1
87	"	6	2	3	2	2	2	2	3	1	2	2
88	"	5	3	3	3	3	3	3	3	3	3	3
89	"	9	2	2	1	2	1	1	2	1	1	1
90	"	10	2	2	1	2	1	1	2	1	1	1
91	"	8	2	2	1	2	1	1	2	1	1	1
92	"	5	3	3	3	3	3	3	3	3	3	3
93	"	5	3	3	3	3	3	3	3	3	3	3
94	"	8	2	2	2	2	1	1	2	1	1	2
95	"	8	2	3	1	2	1	1	2	1	1	1
96	"	4	3	3	3	3	3	3	3	3	3	3
97	"	3	3	4	3	3	3	3	3	3	3	3
98	"	11	2	2	1	2	1	1	2	1	1	1
99	"	7	2	2	1	2	1	1	2	1	1	2
100	"	4	3	3	3	3	3	3	3	3	3	3
101	"	5	3	3	3	3	3	3	3	3	3	3
102	"	6	2	3	2	2	1	1	3	1	1	2
103	"	3	4	4	4	4	4	4	4	4	4	4
104	"	3	4	4	4	4	4	4	4	4	4	4
105	"	6	2	3	1	2	1	1	3	1	1	2

	106	"	3	4	4	4	4	4	4	4	4	4	4
	107	"	3	4	4	4	4	4	4	4	4	4	4
	108	"	3	3	4	3	3	3	3	3	3	3	3
	109	"	3	4	4	4	4	4	4	4	4	4	4
	110	"	12	2	2	1	2	1	1	2	1	1	1
	111	"	5	3	3	3	3	3	3	3	3	3	3
	112	"	3	4	4	4	4	4	4	4	4	4	4
	113	"	1	5	5	5	5	5	5	5	5	5	5
	114	"	1	5	5	5	5	5	5	5	5	5	5

33	"	7	2	3	1	2	1	1	2	1	1	13	1.44	2.7889
34	"	7	2	3	1	2	1	1	2	1	1	13	1.44	2.7889
35	"	3	3	4	3	3	3	3	3	3	4	29	3.22	0.0121
36	"	5	3	3	3	3	3	3	3	3	3	27	3	0.0121
37	"	6	2	3	2	3	1	1	3	1	1	16	1.78	1.7689
38	"	2	4	4	4	4	4	4	4	4	4	36	4	0.7921
39	"	2	4	4	4	4	4	4	4	4	4	36	4	0.7921
40	"	1	5	5	5	5	5	5	5	5	5	45	5	3.5721
41	"	7	2	3	4	2	1	1	2	1	1	13	1.44	2.7889
42	"	6	3	3	3	3	3	3	3	3	3	27	3	0.0121
43	"	4	3	3	3	3	3	3	3	3	3	27	3	0.0121
44	"	3	3	4	3	3	3	3	3	3	3	28	3.11	0
45	"	8	2	2	1	2	1	1	2	1	1	12	1.33	3.1683
46	"	5	3	3	3	3	3	3	3	3	3	27	3	0.0121
47	"	4	2	3	2	2	1	1	3	1	1	15	1.67	2.0736
48	"	6	2	3	2	2	1	1	3	1	1	15	1.67	2.0736
49	"	1	5	5	5	5	5	5	5	5	5	45	5	3.5721
50	"	1	5	5	5	5	5	5	5	5	5	45	5	3.5721
51	JOHN DEREE	9	2	2	1	2	1	1	2	1	1	13	1.44	2.7889
52	STYRE	2	4	4	4	4	4	4	4	4	4	36	4	0.7921
53	"	2	4	4	4	4	4	4	4	4	4	36	4	0.7921
54	"	2	4	4	4	4	4	4	4	4	4	36	4	0.7921
55	"	4	3	3	3	3	3	3	3	3	4	28	3.11	0
56	"	3	3	4	3	3	3	3	3	3	4	29	3.22	0.0121
57	"	6	2	3	2	2	1	1	3	1	1	15	1.67	2.0736
58	"	9	2	2	1	2	1	1	2	1	1	12	1.33	3.1684
59	"	4	3	3	3	3	3	3	3	3	3	27-	3	0.0121
60	"	6	3	3	3	3	3	3	3	3	3	27-	3	0.0121
61	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
62	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
63	"	8	2	2	1	2	1	1	2	1	1	12-	1.33	3.1684
64	"	10	2	2	1	2	1	1	2	1	1	12-	1.33	3.1684
65	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
66	"	5	3	3	3	3	3	3	3	3	3	27-	3	0.0121
67	M.F	9	2	2	1	2	1	1	2	1	1	12-	1.33	3.1684
68	"	6	2	3	2	2	1	1	3	1	1	15-	1.67	2.0736

	69	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	70	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	71	"	3	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	72	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	73	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	74	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	75	"	1	5	5	5	5	5	5	5	5	5	.45-	5	3.5721
	76	"	6	2	3	1	2	1	1	3	1	1	14-	1.56	2.4025
	77	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	78	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	79	"	3	3	4	3	3	3	3	3	3	3	28-	3.11	0
	80	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	81	"	3	4	4	4	4	4	3	4	4	4	36-	4	0.7921
	82	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	83	"	2	4	4	4	4	4	4	4	4	4	36-	4	0.7921
	84	"	4	3	3	3	3	3	3	3	3	3	27-	3	0.0121
	85	"	9	2	2	1	2	1	1	2	1	1	12-	1.33	3.1684
	86	2	2	1	2	1	1	1	1	1	12-	1.33	3.1684	1.33	3.1684
	87	2	3	2	2	2	2	2	1	2	18	2	1.2321	2	1.2321
	88	3	3	3	3	3	3	3	3	3	27-	3	0.0121	3	0.021
	89	2	2	2	2	1	1	1	1	1	13-	1.44	2.7889		
	90	2	2	2	2	1	1	1	1	1	13-	1.44	2.7889		
	91	2	2	2	2	1	1	1	1	1	13-	1.44	2.7889		
	92	3	3	3	3	3	3	3	3	3	27-	3	0.0121		
	93	3	3	3	3	3	3	3	3	3	27-	3	0.0121		
	94	2	2	2	2	1	2	1	1	1	14-	1.56	2.4025		
	95	2	3	3	2	1	1	1	1	1	15-	1.67	2.0736		
	96	3	3	3	3	3	3	3	3	3	27-	3	0.0121		
	97	3	4	4	3	3	3	4	3	3	30-	3.33	0.0481		
	98	2	2	2	2	1	1	1	1	1	13-	1.44	2.7889		
	99	2	3	3	2	1	2	1	1	1	16-	1.78	1.7689		
	100	3	3	3	3	3	3	3	3	3	27-	3	0.0121		
	101	3	3	3	3	3	3	3	3	3	27-	3	0.0121		
	102	2	3	3	2	1	2	1	1	1	16-	1.78	1.7689		
	103	4	4	4	4	4	4	4	4	4	36-	4	0.7921		
	104	4	4	4	4	4	4	4	4	4	36-	4	0.7921		
	105	2	3	3	2	1	2	1	1	1	16-	1.78	1.7689		
	106	4	4	4	4	4	4	4	4	4	36-	4	0.7921		
	107	4	4	4	4	4	4	4	4	4	36-	4	0.7921		
	108	3	4	4	3	3	3	3	3	3	29-	3.22	0.0121		

	109	4	4	4	4	4	4	4	4	4	36-	4	0.7921		
	110	2	2	2	2	1	1	1	1	1	13-	1.44	2.7889		
	111	3	3	3	3	3	3	3	3	3	27-	3	0.0124	$\sum$ Yi=	354.17
	112	4	4	4	4	4	4	4	4	4	36-	4	0.7921	$\bar{Y}$ =	354.17/114
	113	5	5	5	5	5	5	5	5	5	45	5	3.5721		
	114	5	5	5	5	5	5	5	5	5	45	5	3.5721	=	3.11
		81	87	87	81	71	75	72	71	71	20535				
		367	395	356	368	337	349	335	333	345					

$\sum y_{ij}^2 = 11376$

$\sum y_i = Y = 3186$

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	SPECIFIC GRAVITY	MELTING POINT (^0C)	BOILING POINT (^0C)
Lead	Pb	82	207.19	11.344	327	1620
Antimony	Sb	51	121.75	6.684	630.5	1380
Tin	Sn	50	118.69	7.28	231.9	22.70
Arsenic	As	33	74.9216	5.727	814	.615 sublimes