PERFORMANCE EVALUATION OF THE POWER DISK - A PTO DRIVEN DISK TILLER.

by

Solomon Tembo

A THESIS

Submitted to the
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Engineering

1986.

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Solomon Tembo

Date: January 17, 1986

Approved: Thomas H Burkhardt
Co-major Professor

Approved: Robert H. Wilkinson
Co-major Professor

Approved: [illegible]
Department Chairman

Approved: John B. Gerrish
Committee Member

ABSTRACT

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Quantitative performance evaluation of a Japanese-made PTO-driven disk tiller was carried out using a microcomputer-based data acquisition system. A tractor was instrumented to measure PTO speed, PTO torque, vertical and horizontal forces on the three-point-hitch, ground speed and drive wheel speed. Soil moisture and tillage depth were measured separately.

Field tests were conducted in the Fall 1985 to determine the drawbar power, PTO power and total power requirements of the implement. Results indicate that approximately 10% of total power requirement was obtained through traction to the implement and 90% of total power requirement to the implement was transferred through the PTO drive shaft. Significant saving (30%) in energy utilization was attained at a peripheral disk velocity to ground speed (pdv/gs) ratio of 2.5. No energy savings were attained at higher peripheral disk velocities as total specific power increased with increases in peripheral disk velocity.

The effect of PTO powering on the quality of work was evident in soil conditions close to field capacity. An acceptable level of soil pulverization and mulch incorporation was observed at a pvd/gs ratio of 2.5. The implement's tillage performance was severly handicapped in dry soil conditions.

To the late Taruziva Fambai Gwarazimba Dube and Absalom F.G. Dube.

You are a source of unparalleled inspiration.

ACKNOWLEDGEMENTS

The author expresses his sincerest appreciation to the following persons and organizations for their contribution to this study:

To Dr. Thomas H. Burkhardt, research leader and co-major advisor, for his professional guidance and support throughout this study. His attention to research detail was positively educative and will serve me well in my future research work.

To Dr. Robert H. Wilkinson, academic advisor and co-major research advisor, for his guidance and optimism throughout the course of my studies.

To Dr. John B. Gerrish for his time and positive criticism as committee member. His expertise in measurement theory and application was indeed invaluable.

To the technical personnel in the research laboratory, for the help rendered in putting the project hardware together.

To Toyosha Company of Japan, for their technical and financial support of this study.

To Dr. Makoti Hoki and the Agricultural Machinery Laboratory of Mie University in Japan, for the supply of the torquemeter.

To Mr. Milton Mah, a fellow graduate student under the guidance of Dr. Burkhardt, for his computing expertise, companionship, helpful criticism, and those long discussion sessions which made this study a worth-while experience.

To my fellow graduate students, whose advice both socially and academically served me well throughout my study here.

To the people and Government of Zimbabwe, for the opportunity offered to persue further studies in the hope for a better, future Zimbabwe.

Finally to my mother Fungai, family and friends for their unfailing love, encouragement and confidance in my quest for knowledge.

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INTRODUCTION

The need for field performance data of farm tractors and implements has become an absolute necessity. The high cost of owning and operating the machinery used in production agriculture makes it imperative that the tractor-implement system be properly matched with respect to implement width and tractor power and mass. Zoz (1972) noted that often the matching of tractors and implements for field operations has simply been based upon prior experience instead of a thorough knowledge of the performance factors involved. The predictable result has been less than optimal performance. Garner, Wolf and Davis (1980) observed that the most beneficial role that engineering research can perform in the tillage/energy area, is to assist in selecting tillage systems for effective energy use. This research must be of an applied nature dealing with actual field conditions which a farmer may encounter in a given area. Reynolds, Miles and Garner (1982) commended engineering research torwards the increased application of computer-based data acquisition systems for collecting and processing data related to energy requirements in field operations. They argued that actual field evaluation as opposed to laboratory assessments are more indicative of performance and efficiency of tractor-implement match-up and therefore more beneficial to the farmer.

This is the research approach that the Department of Agricultural Engineering at Michigan State University adopted. In a joint research effort with Mie University of Japan, which was funded by Toyosha

Company Ltd, the department undertook field performance evaluation of the Power Disk under Michigan conditions. The ultimate goal of this research was to make field performance data available to the Michigan farmers. Tests peformed by Toyosha Company have shown a significant reduction in draft and power requirements. Independent emperical data was to be collected and analyzed for typical Michigan field conditions.

The overall objective of the research effort was to investigate drawbar power and PTO power requirements of the Power Disk, with the aid of an in-field microcomputer data acquisition system.

1.1 The Power Disk

The *Power Disk came to the Department of Agricultural Engineering at Michigan State University, from the Toyosha Company of Japan, as part of a collaborative research effort with the Department of Agricultural Engineering at Mie University, Japan. The Power Disk is a PTO driven disk tiller developed by Toyosha Company, Ltd of Japan. It was introduced into the Japanese market in April, 1983. It is currently being marketed in the United States by the Bush Hog Company.

Power is transferred from the PTO shaft to the disk blades through a centrally located gear box, followed by a roller chain drive which is enclosed in an oil bath (Figure 1.1). The peripheral disk velocity (pdv) at a PTO speed of 540rpm is 13.4 Km/h and is 25 Km/h at a PTO speed of 1000 rpm. These velocities are 3 to 5 times greater than normal operating ground speed (gs). The disk blades rotate in the same direction as that of the tractor wheels, thus creating a forward thrust, which adds to the forward thrust of the tractor and reduces

*Use of trade names in no way constitutes an endorsement of any particular manufacturer or product.

implement draft.

Direct transfer of available power from the tractor engine to the implement is more efficient as compared to the conventional tractive method. The implement manufacturers claim that this direct transfer of power permits the use of 30% smaller tractor sizes than would used when the conventional tractive method is employed. The general specifications of the Power Disk are shown in Table 1.1.

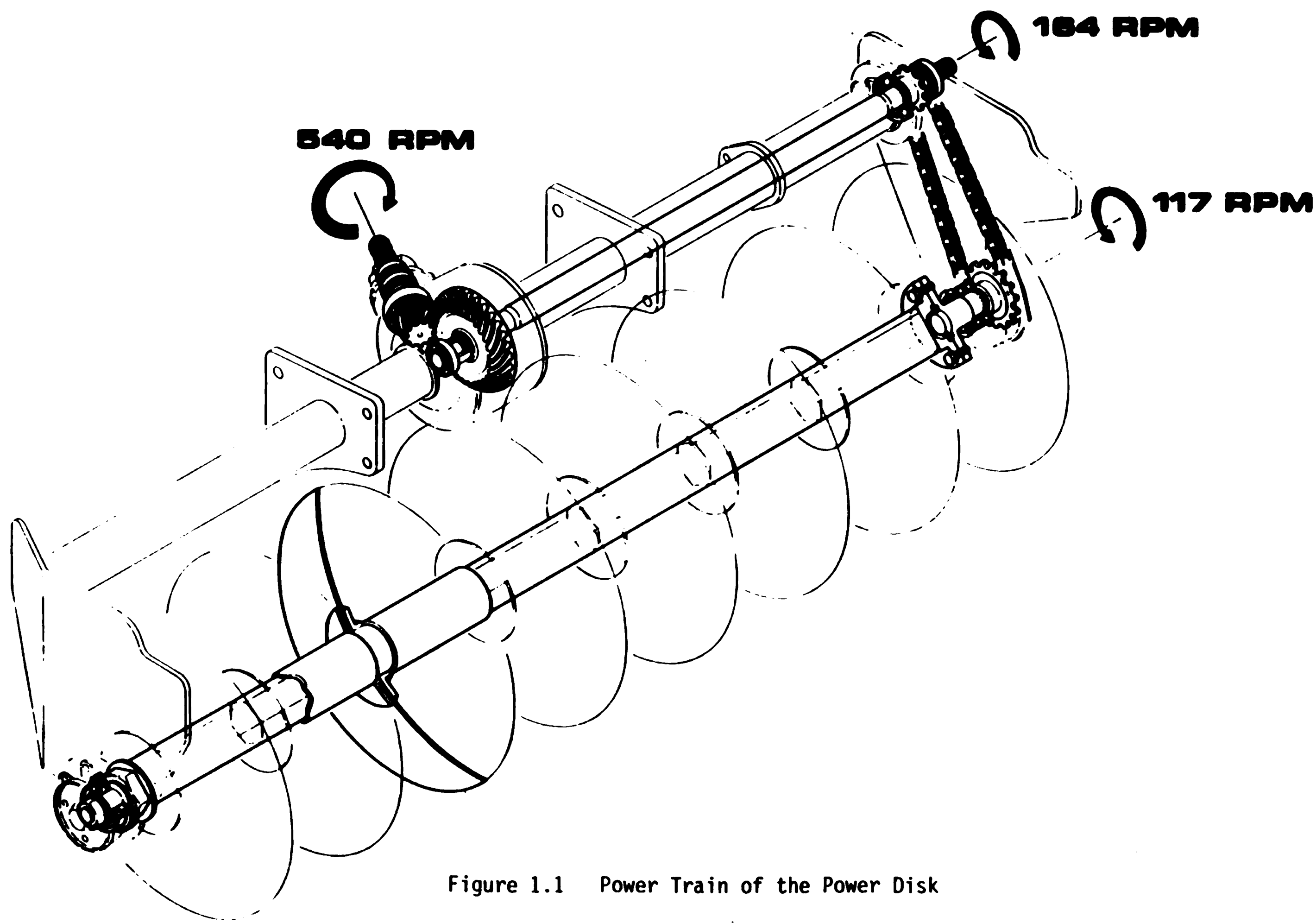


Figure 1.1 Power Train of the Power Disk

MODEL	F 800
DIMENSIONS:	
OVERALL LENGTH	2170 mm (85 in.)
OVERALL WIDTH	2100 mm (82 in.)
OVERALL HEIGHT	1050 mm (41 in)
MASS (WEIGHT)	485 Kg (180 lbs)
NUMBER OF DISK BLADES	8
DRIVING SYSTEM	BEVEL GEAR AND ROLLER CHAIN
DISK BLADE DIAMETER	633 mm (25 in.)
EFFECTIVE WIDTH	2000 mm (79 in.)
PLOWING DEPTH (MAX)	300 mm (12 in.)
DISK ANGLE SETTING	27 AND 31 DEGREES
WORKING SPEED	3 - 5 Km/h (2 - 3 mph)
APPLICABLE TRACTOR (PTO HP)	15 - 25 Kw (20 - 30 HP)
MOUNTING HITCH	3 POINT HITCH
OPTIONAL PARTS	WEIGHTS: 15 Kg * 8 PIECES :(33 lbs * 8 PIECES)

SOURCE: TOYOSHA TECHNICAL LITERATURE

Table 1.1 Specification of the Power Disk

CHAPTER II

LITERATURE REVIEW

2.1 Basic Disk Design and Geometry

Early research on soil-disk plow relationships was directed at developing a sound scientific basis for implement design and use. This research focused on problems involving draft, forward speed, soil throw, residue coverage and penetration, as they related to size, disk concavity (radius of curvature), weight, hitches, gang angles and other questions of materials and adjustment. While this information was essential for good design, empirical in-field data are required to improve implement operating efficiency. Such applied data were first generated in the 1970's as an outgrowth of the energy crisis and the technological breakthrough brought about by in-field microcomputer data acquisition systems.

While the objective of this study was not to redesign the Power Disk, a review of the literature on basic design is essential to a complete understanding of the operation of the implement. One of the first reports dealing with the dynamics of the modern disk harrow was made by Mckibben (1926). By general analysis of soil forces acting on the offset harrow, he showed how, with proper arrangement of gangs, it "was possible to design a disk harrow which tills a strip, the center of which is offset from the center of the tractor and which at the same time operates without side draft upon either the harrow of the tractor." By changes in the hitching arrangement, the offset harrow could operate on either side of the tractor and throw soil to and from the citrus trees it was being used to cultivate. Sjogren (1936), outlined the evolution of the offset harrow and listed the broad requirements for the design of complete implements.

Measurement of soil forces acting on disks was undertaken by Clyde (1939) under semi-controlled field conditions. The effect of disk angle, angle of inclination, disk diameter and moisture content of the soil were observed and provided an analytical guide for the design of implements and proper hitching procedures. Disk angle refers to the angle in the soil surface plane, between the central axis of the disk and a line perpendicular to the direction of travel. However, the instrumentation available at the time imposed severe limitations on his ability to collect data for a wide range of conditions.

Gordon (1941) contributed most significantly by analyzing a single blade disk plow at the Tillage Machinery Laboratory TML (USDA), using two firmly packed soils (a Decatur clay and a Davidson loam) in a soil bin. The instrumentation employed was based on the principle of the dynamometer developed earlier by Clyde. The disk was held in a framework through which the reaction of the soil on the disk was imparted to six hydraulic cells. The cells, in turn, actuated Bourdon tube type elements to which pens were attached. From this record of pressures, the soil reactions on the disk were resolved into three directional components : the force required to pull the disk forward (the draft force); the vertical reaction upward or downward on the disk; and the side thrust. Over a range of moisture conditions considered optimum for tillage, attention was paid to the draft, vertical and side forces as well as to the thrust perpendicular to the plane of the disk. Gordon observed that soil types and soil conditions produced the most pronounced differences in soil reactions on the disk.

Specifically, he found that:

1. Upward thrust on the disk decreased as the disk angle was increased, thus improving soil penetration;

2. Minimum draft was attainable at a disk angle of about 45 degrees, and that draft increased rather sharply for disk settings above 45 degrees;

3. Draft requirements increased with increases in speed (a 67% increase in draft was observed with an increase of speed from 2.5 to 5mph for the sandy loam);

4. The draft and upward thrust of the soil increased with increases in disk concavity (decreases in radius of curvature); and

5. The increase in soil reaction on the disk as the speed increased was caused by the soil being thrown a great distance forward and to the right at higher speeds, with a net reduction in tillage depth.

McCreery and Nichols (1956) studied the effects of disk geometry on soil factors at the TML (USDA). They found that at small disk angles the back or the convex side of the disk blade will exert pressure on the soil, causing the soil to compact. This part of the disk is the bearing area, and is similar to that part of a wheel which contacts the ground. Like the wheel, the bearing area of a disk resists penetration, however, if it does penetrate then the draft is large. To minimize the draft and assist penetration, therefore, the bearing area should be zero. The concave side of the disk which contacts the soil, is the pressure area. The application of pressure causes the soil to rupture and pulverize. The pressure area is analogous to the share and moldboard of the moldboard plow.

The bearing and pressure areas depend on the disk diameter, tillage depth and disk angle. The bearing area is reduced with a decrease in diameter, a decrease in tillage depth, and with an increase in the disk angle. At some critical angle the bearing area is Zero. McCreery and Nichols determined this angle graphically and found that it is attained when the tangent to the disk surface, at the leading edge of the intersection of the disk and the soil surface, is parallel to the direction of travel. Harrison and Thivavarnvongs (1975) in their study of soil reacting forces from laboratory measurements with disks developed a functional relationship between the minimum disk angle for zero bearing area, radius of curvature, the disk diameter, and tillage depth. They concluded that the minimum critical disk angle was significant in denoting the presence or absence of the disk bearing area because the bearing area significantly affected the soil reacting forces and the screw axis and, thus the performance of disk implements.

In the most recent studies on the influence of disk curvature on soil penetration, Gill et al. (1982) concluded that increasing the radius of curvature of disks while selecting proper disk angle and mass, had a profound effect on penetration. They argued that the change in penetration depth is a function of the forces acting on the back and front surface of disks, as indicated in ealier studies by McCreery et al. (1956). They found that reducing the force on the back surface of the disks by increasing the radius of curvature or by increasing the disk angle in a range of 0.20 radians to 0.35 radians, or both, caused a reduction in the magnitude of draft and vertical forces.

The increase in disk penetration is important because of the possibility of developing lighter disk plows that will penetrate to desired depths without ballasting. The lighter tillers are of particular interest from the standpoint of the development of powered disk tillers, improvement of fuel economy, reduction in soil compaction and control of tillage depth.

2.2 Power Driven Disks.

Early findings on free rolling disks by Mckibben (1926), Gordon (1939) and McCreery and Nichols (1956) have remained unchallenged and have provided the theoretical basis for the studies on the dynamics of powered disks initiated by Getzlaff (1953) and Getzlaff and Sohne (1959). The studies of Getzlaff et al. were carried out on an experimental single disk blade plow connected to a frame fitted with six transducers, much like Gordon's (1941) instumentation package. The disk was driven by a 3.2Kw direct current motor, powered from a generator fitted on a 55 HP Hanamog tractor. Power from the motor to the disk blade was transmitted via four v-belts to a worm shaft; the worm wheel was mounted on the hub shaft of the plow disk. They varied peripheral disk velocity over a wide range by regulating the engine speed and interchanging the belt drives. Disk geometric parameters (disk diameter,radius of curvature and disk angle) were kept constant. The tests were performed on hard clayey soils.

Getzlaff and Sohne (1959), investigated the three component soil forces; the longitudinal(L), vertical(V) and lateral (S) forces. Longitudinal forces increased rapidly with increasing tillage depth but were observed to decrease with inreasing peripheral disk velocity. A maximum reduction of 30 % was observed when compared with an unpowered disk at a peripheral disk velocity to ground speed (pdv/gs) ratio of 1.3. Lateral and vertical forces were influenced unfavorably by the drive. With increasing peripheral speed the lateral forces and the vertical forces became larger.

Disk drive power requirements inceased sharply with peripheral disk velocity . Total power expenditure (drawbar + slip loss + disk drive power) rose with increasing peripheral velocity and was greater than that of free rolling disks. The extra power expenditure was approximately 13 % to 25 % with the pvd/gs ratio of 1.3 and over 50 % with a pvd/gs ratio of 2.5. Power expenditure was thus a function of the pdv/gs ratio, and a ratio of 1.3 indicated an acceptable level of energy utilization.

At higher peripheral disk velocity, the soil was thrown further and the furrow width made wider. They observed greater clod break up and greater residue incorporation with the powered disk than with the free rolling disks. At a peripheral disk velocity equal to 2.5 times the ground speed, Getzlaff et al. observed greater disk slip against soil particles flowing off the disk without considerable energy impulses being imparted to them. This, they argued, confirmed that the pdv/gs ratio was not to exceed 1.3 for efficient disk operation. In conclusion to their studies, Getzlaff et al. stated that the driven disk did not bring any significant benefits in energy utilization. Moreover, both the lateral and vertical forces were influenced unfavorably, making the design more complex and costly.

Sohne (1963), in a comparative study of the quality of work between the conventional disk plow and the powered disk, observed that with a powered disk soil pulverization resulted, whereas use of a free rolling disk plow caused large clods. While acknowledging the single pass advantage of the powered disk, he warned of possible destruction of soil structure by rigorous action of the powered disk. With respect to power consumption Sohne observed that :

1. Increasing the pdv/gs ratio from 1.3 to 1.5 reduced drawbar pull by 30% and increased power consumption by 120%;

2. Doubling the disk peripheral velocity reduced drawbar pull to

half, but then the total power requirement increased to 170%,

3. With increased disk peripheral velocity the side and vertical forces became larger; and

4. Compared to the free rolling disk, the high power requirement, the relatively low reduction in draft, the difficulties involved in design and high costs, the development of the power driven disk could not be justified.

Abernathy (1976) also concluded, from laboratory tests on a self-powered disk, that draft requirements could be reduced by 20%, but the total power required was 3 to 6 times greater than the total power required for free rolling disks.

Young (1975) conducted a power disk (DynaTil) field evaluation. The DynaTil was a fabricated implement, intended to test the concept of powering disks. The tandem disk used was powered hydraulically. Power was provided from a tractor's 1000 rpm PTO drive shaft via two variable-displacement, pressure-compensated hydraulic pumps mounted on the DynaTil. Peripheral disk velocity was contolled by a pump flow rate control at the operator's platform.

Over a wide range of field conditions, Young found the effect of powering to be most evident in wet soil conditions where penetration was good. Greater control of the degree of pulverization and mulch incorporation was also achievable under wet soil condition, however poor traction was observed under the wet conditions and that tended to increase slip significantly. Even so, slip for the DynaTil was significantly less than that of a free rolling disk plow, approximately 70% less the slip of the free rolling disk in all field conditions.

With increased pdv/gs ratio, Young, reported significant increases in horsepower requirements for the DynaTil. Estimated drawbar power (PTO power equivalent) for the DynaTil was generally lower than that of a free rolling disk at lower ground speeds (4 mph) and significantly larger above 7.5 mph. The DynaTil had no tillage depth control mechanism and was limited to a maximum depth of 15 cm by its physical structure.

In conclusion Young recommended the use of a mechanical drive to transfer power from the tractor to the implement. He cited the lower power requirements for mechanical drives and the low machine cost (when compared to hydraulic drive systems) as justification to encourage production of such power implement. Furthermore he argued that the greater farmer productivity and on-the-go controllability in soil pulverization and mulch incorporation, outweighed the expected increased cost due to the powering of the disk blades.

Young's positive energy and field productivity appraisal of the powered disk (despite the earlier negative cost-benefit analysis by Getzlaff et al.) probably encouraged the Toyosha Company to develop the Power Disk. Toyosha claims the Power Disk assures lower costs (both fuel consumption and wheel tire pressure on soil are reduced by 50%) through high performance therefore increasing the potential for higher profits.

2.3 Instrumentation

Energy limitations have directed agricultural engineering researchers to study and improve the efficiency of field machines through the conduct of field data studies as opposed to laboratory data experimentation. During the 1970's microcomputers were increasingly utilized in the acquisition and processing of implement-tractor performance data. The data acquisition systems varied in complexity from the measuring of one or two parameters, as is common in performance monitors, to the monitoring of many parameters simultaneously. The construction, capacity and versatility of these instrumentation packages varied according to individual data collection constraints.

Harter and Kaufman (1979), Lin et al.(1980), Bedri et al.(1981), Hendrick et al.(1982), Smith et al.(1981), Stange et al.(1982) and others described systems that monitored, collected and stored data . Although similar in function, each system was specifically tailored to individual data collection needs. Luth et al.(1978), for example assembled a sophisticated microcomputer telemetry system capable of receiving 31 channels of data, sampling at a rate of up to 50,000 samples per second. Their system could process data in the field, delivering either video displays, hard copy prints of tabular data summaries or graphs of various functional relationships. Lin et al.(1980) developed a microcomputer-based data acquisition system for measuring in-field tractor performance. Their system could collect data from 16 differential input channels. They measured engine speed, ground speed, fuel flow, fuel temperature, axle torque, axle weight and draft. The system featured selected gains and memory storage of data, with a data dump cassette for use when the experiments were completed. Grevis-James et al. (1983) reported on a data acquisition and processing system, using two Rockwell Aim 65 microcomputers. The system measured drawbar pull and power, ground speed, wheel slip, fuel flow and engine speed. One microcomputer was installed on the tractor to collect, display and store the data on magnetic tape. The system provided an immediate hard copy output, which provided the operator with a check on system functioning and data quality. The second microcomputer was operated from the laboratory and was used to process and transfer data stored on magnetic tape to an IBM 370 mainframe computer for analysis.

Carnegie et al.(1983) reported on the use of an APPLE II personal microcomputer (similar to the one employed on this project) for data collection and analysis. The personal microcomputer was versatile, yet inexpensive, and performed well under adverse field conditions.

Tompkins and Wilhelm (1982) developed a versatile system which featured sampling rates variable from 0.1 second to 4.5 minutes. A portion of the sampling period could be measured and observed to 1/120seconds. The system had 24 program options which included calibration routines, examination of previously recorded data, data acquisition , start and stop, among other special purpose options.The system measured drawbar force, fuel consumption and engine speed. In a subsequent study Freeland, Welhelm et al.(1984) developed instrumentation for in-field measurement of PTO driven agricultural implements. In addition to the description of the sensors and hardware required for the measure of PTO driven implements, they emphasized the special considerations involved in measuring torque. They recommended that analog signals be sampled at consistant frequencies equal to or greater than twice the frequency component of the highest frequency component of interest (the Nyquist frequency) and that low-pass filters having cutoff frequencies of 1/2 or less than the sampling frequency should be used, if the required sampling rate is not practical.

2.4 Summary

The evolution and the design of concave spherical disks has been reviewed extensively. The geometric parameters of these disks have been shown to be significant with respect to their efficient operation. Few studies were found which investigated the design and the performance of the powered disks. The few studies carried out on the powered disks, have been inconclusive in their findings. Some researchers (Getzlaff and Sohne (1959)) argue that the small reduction in draft, against the significant increase in total power requirements (to be had in the powered disk when compared to the free-rolling disk) does not justify the cost of developing such an implement, yet others (Young (1975)) cite the potential increase in farmer productivity as being worth the research effort and cost .

Microprocessor-based data acquisition systems have emerged as relatively inexpensive alternative to instrumentation-type tape-recorder or strip chart systems. The microprocessor systems have enabled collection of field data. These data facilitate efficient tractor-implement match-up, thus reducing energy waste at the farm level. Performance parameters reviewed included draft, velocity, torque and fuel consumption.

CHAPTER III

OBJECTIVES

For decades the question of how the efficiency in transmission of power from the engine to the drawbar of a tractor might be improved has remained unresolved. The losses that occur at the soil contact surface of the tractor drive wheels have increased in significance due to escalating energy costs.

Newly designed agricultural tires have improved the tractive ability of agricultural tractors under ideal conditions. As energy costs escalate researchers need to direct their efforts at efficient energy transfer from the engine to the implement under the adverse conditions typical of most farm operations. This could potentially reduce energy costs and timeliness penalties at the farm level.

The literature reviewed suggested that the large increases in total power expenditure far outweigh the small savings in drawbar power requirements to be had by transmitting engine power through the PTO to the implement. On the other hand Toyosha Company tests claim that the PTO driven disk tiller; the Power Disk, will save farmers as much as 30% in total power requirements, thus reducing overall machinery operating costs at farm level. These two divergent positions raised the question: How efficient is this particular technological innovation (the Power Disk) at transmitting engine power to the disk blades?

The objective of the study, therefore, was to investigate the draft and power requirements of the Power Disk with the aid of an in-field microcomputer data acquisition system. More specifically the objective was to measure:

1. Draft requirements
2. PTO torque
3. PTO speed
4. Ground speed
5. Drive wheel speed
6. Drawbar power requirements
7. PTO power requirements
8. Total power requirements
9. Tillage depth
10. Quality of the tillage operation (i.e. mulch incorporation, soil pulverization and surface roughness)

CHAPTER IV

THE EQUIPMENT

4.1 Introduction to the Instrumentation System.

In this chapter, components of the instrumentation system will be presented. The data aquisition hardware and software will be described and discussed in detail.

A decision was made to instrument one tractor and use that tractor to operate the PTO driven disk tiller over the desired range of field and operating conditions. While this approach effectively eliminated the possibility of evaluating the effect of using different tractors; various implements and operating conditions could be compared quantitatively based on that one tractor. Furthermore, this decision minimized the possibility of any structural damage to the data acquisition hardware due to handling.

The design objectives that guided the development of the data acquisition system were:

1. System flexibility; the microcomputer was to be readily adaptable to various fuctions and be flexible in operation.

2. System documentation; the system was to be fully documented to allow subsequent use by any reseachers in the department.

3. High volume and high speed data storage; large RAM (RANDOM-ACCESS-MEMORY) capacity for whatever sampling rates were to be used in tillage studies.

4. Durable and compact; required to withstand the adverse field conditions and be small enough to fit in a tractor cab.

The microcomputer chosen was the Apple IIe system. An AI13 Analog to Digital (A/D) converter (Interactive Inc.) was chosen to interface each analog signal to the microcomputer. An M1000 series (Data Capture Technology) signal conditioner provided the required conditioning of all signals from the transducers to the A/D converter. The tractor utilized for this research project was a Ford 7610, 68.84Kw (86.95hp), front-wheel assist, diesel, with a standard enclosed operator's platform. Manual functions associated with the data acquisition were strategically placed to facilitate effective unassisted operator control. Figure 4.1 shows how the transducers were connected to the data acquisition system. The following section describes each transducer in detail and its location in relation to the whole system package.

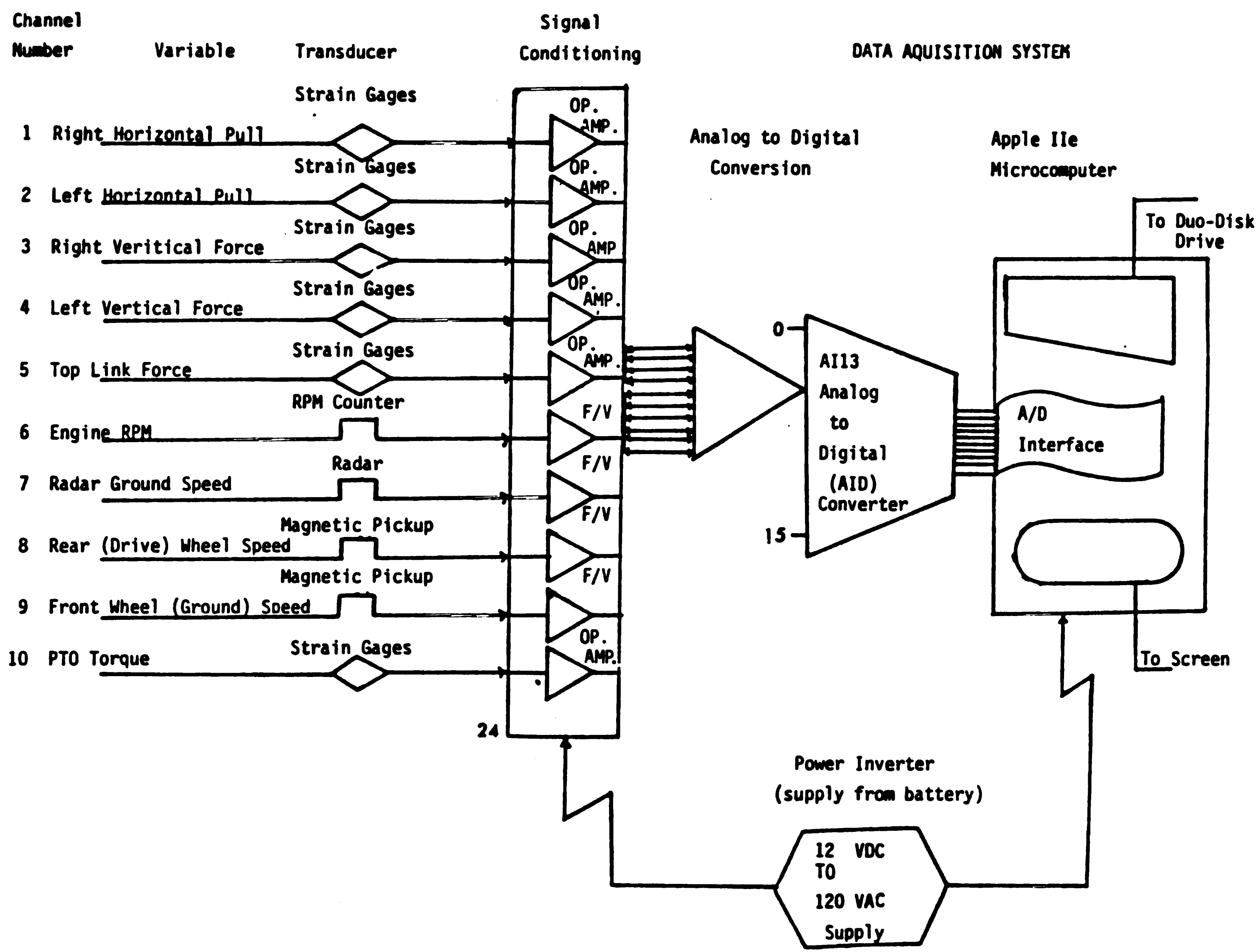


Figure 4.1 Block Diagram of the Data Acquisition System Hardware

4.2 Instrumentation and Sensors.

4.2.1 The Dickey john Tractor Performance Monitor II (DjTPMII)

During the preliminary evaluation of the PTO driven disk tiller, a commercially available Dickey john Tractor Performance Monitor II (DjTPMII) was used. The DjTPMII is a computerized console which mounts inside the tractor cab and displays information such as engine speed, ground speed, percent drive wheel slip, distance travelled and area covered per hour. Information is supplied to the console by four sensors:

1. An implement status switch which relates position of an implement on the three point hitch,
2. an engine rpm sensor used for determining engine speed,
3. a single beam Doppler radar unit for determining true ground speed and
4. a magnetic pick up sensor used in conjunction with the radar unit to determine percent drive wheel slip.

Although the DjTPMII was not an integral part of the final instrumentation package, output signals from the Doppler radar unit and the engine rpm sensor were simultaneously routed to the data acquisition system. The Doppler radar unit was used to verify the front wheel rotational speed sensor.

4.2.2 Radar Ground Speed Measurement.

Radar ground speed measurement was obtained by using the frequency generated from the DjTPMII radar unit. The radar unit and mounting bracket were installed so the face of the unit projected into an unobstructed view of the ground (earth's surface) when angled towards the rear of the tractor. The sensor operated by directing a beam of microwave energy at the ground and comparing the frequency of the energy reflected back from the ground with that sent out. If there was movement of the sensor relative to the ground, the reflected frequency would be different from the transmitted frequency (Doppler effect). The difference between the transmitted and received (reflected) frequencies was proportional to the vehicle speed. The value of the Doppler frequency shift Fd was given by:

$$Fd = 2Vg/\lambda \cos \theta$$

where:

Vg is the magnitude of the velocity vector (44.7cm/sec.=1MPH)
λ is the wavelength of the transmitted signal (1.243cm for 24.125GHz.)
θ is the angle between the velocity vector and the center of the antenna beam (nominally 35 degrees)

The nominal angle setting of the radar unit which determined the accuracy speed measurement, was set and checked with a calibrated face plate and plumb bob. The frequency output from the radar unit was channelled through a Frequency to Voltage(F/V) converter, so the AI13 Analog to Digital(A/D) converter could read it. The F/V converter applied was an M1080 10KHz converter. Specifications on the radar unit performance are outlined in Appendix B.1.

4.2.3 Engine Speed Measurement.

Engine speed was obtained using the frequency signal generated by the DjTPMII engine rpm sensor. The engine rpm sensor fit between the existing mechanical drive sender and the tachometer cable leading to the operator's console. The sensor contained a separate keyed drive pin that inserted into the tachometer drive sender. As the sender rotated, the sensor generated a frequency proportional to engine speed. The frequency signal from the sensor was routed through an M1080, 10KHz F/V converter, so it could be read by the AI13 A/D converter. Specifications are in Appendix B.2. Calibration of the engine rpm sensor was verified by comparing its output values to corresponding output values on the DjTPMII display and the tachometer dial readings located on the operator's console.

4.2.4 Front and Rear Wheel Rotational Speeds.

Ground speed, percent slip of the drive wheels and the peripheral disk velocity to ground speed (pdv/gs) ratio are the parameters computed using measured wheel speed rotational speeds. The pdv/gs ratio is a parameter related to hitch forces, power requirement, soil physical condition and the quality of work produced by the passage of the power disk tiller. The pdv/gs ratio as it relates to the quality of work, hitch forces, and power requirement is discussed in greater detail later in the report.

To measure the front and rear wheel rotational speeds, magnetic pickups supplied by Wabash Inc., Huntington, Indiana were used. In tachometry applications, such as this, magnetic pickups produced an output frequency from an actuating sprocket in direct proportion to the rotational speed. The signal produced in this mode was given by;

$$\text{Frequency (Hz)} = \text{Number of sprocket teeth} * \text{wheel rpm}/60$$

The frequency produced was then converted directly to wheel rpm by means of a frequency-to-voltage converter (M1080).

The front wheel rotational speed sensor in the 2WD mode of the tractor used for the tests served as the ground speed measuring sensor. The front wheel rotational speed sensor consisted of a 60 tooth sprocket mounted on the inner hub of the front wheel and a cylindrical pole piece magnetic pickup (model 60-0198"G"-2.5 in. threaded reach) was mounted perpendicular to the sprocket teeth. The sprocket was accurately machined to fit the external diameter of the hub, and a metal-to-metal bonding material was applied to hold the sprocket in place.

Magnetic pickups are normally mounted with their centerline parallel to the sprocket's plane, however due to space limitations the sensors (front and rear wheel) were mounted perpendicular to the sprocket's plane, without detectable loss in measurement accuracy. The magnetic pickup was held in position by a "vibration-free" holder bolted on the front wheel axle beam. Air gap adjustment was achieved by turning the sensor on its threads and holding it in place by a lock nut. The sensor was set for maximum sensitivity at the lowest expected operational ground speed.

The rear wheel rotational speed measurement was used primarily for determining the drive wheel slip, in the 2WD mode. The rear wheel rotational speed sensor consisted of an 80 tooth sprocket mounted on the inner hub of the rear wheel and a Wabash Inc. cylindrical pole piece magnetic pickup (model 60-0198"G"-2.5 in. threaded reach), mounted in the same manner as the front wheel speed sensor.

The magnetic pickups were chosen for their wide air gap tolerances , high output signal with coarse sprocket teeth and their insensitivity to orientation. Output signals from both the front and rear wheel rotational speed sensors were each channelled through an M1080 10KHz, F/V converter. Calibration information for both the front and the rear wheel rotational speeds is outlined in Appendix B.3. Front and rear wheel rotational speeds were verified against the radar speed sensor on a flat asphalt surface.

4.2.5 PTO Torque Measurement.

A torquemeter similar to the ones commercially employed to measure torque in shafts, was built and supplied by Dr. Hoki and the farm machinery laboratory personnel at Mie University, Japan.

This torquemeter, measures torque by using strain gages and a slip ring collector. The PTO torque transducer consisted of a four-arm, 120-Ohm, active Wheatstone bridge which required an excitation level of 2 volts.(Figure 4.2) Strain gages were mounted on either side of the thinner dimensions of the PTO shaft universal joint arms. Signals from the strain gages were transferred to the signal conditioner through the slip ring collector mounted on the shaft by two tapered sleeves. The PTO torque sensor circuit was arranged to detect torque in both clockwise (+) and counter-clockwise (-) directions. Self-temperature compensating type gages were employed and all bending strains were to be cancelled by this gage arrangement on universal joint arms.

To enable the AI13 A/D converter to read the low level output signal from the strain gages, a strain gage signal conditioner was employed. An M1000 series (signal conditioning module, model M1060, Data Capture Technology, Tulsa, Oklahoma.) was employed. The M1060 consists of a high quality difference amplifier with a variable stage gain (range: 0 to 5 000), adjustable transducer excitation voltage (range: 3 to 12 Volts) and provision to lower the excitation voltage (to a value less than 3 Volts), by adding the appropriate resistance to the module as was done for the 2 Volts excitation required for the

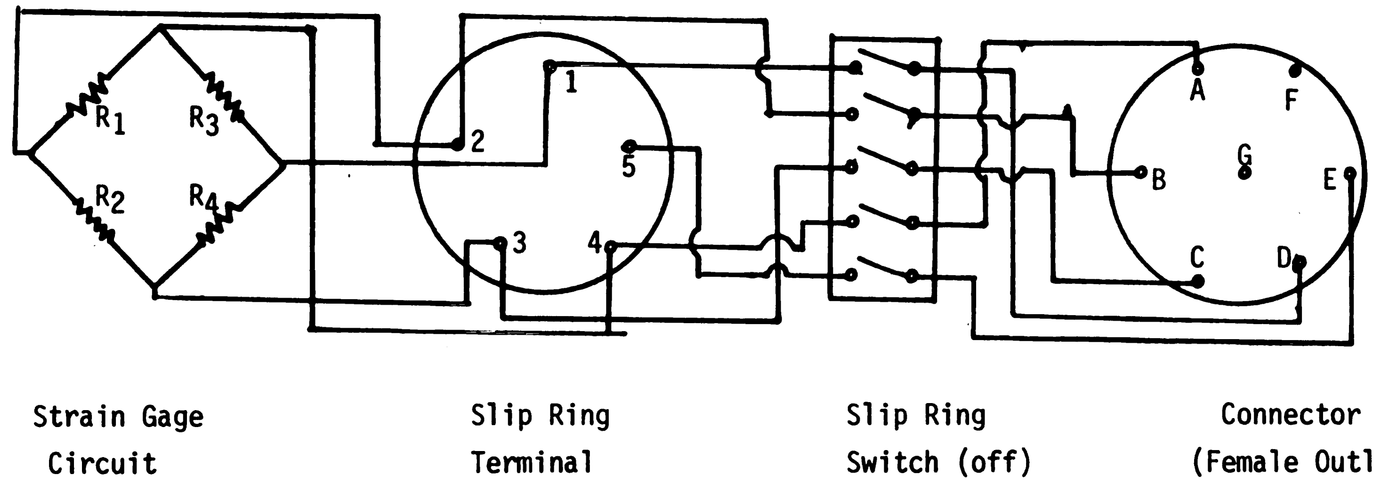


Figure 4.2 Slip Ring Circuit of the PTO Torque Transducer

torquemeter Wheatstone bridge. Performance specifications of the M1060 are listed in Appendix B.6.

By applying the M1060 strain gage signal conditioner, the low level millivolt strain gage signal was amplified to the standard voltages (-5 to +5 Volts), detectable by the AI13 A/D converter.

Specifications and calibration information on the torquemeter is presented in Appendix B.4. The torquemeter was subjected to moment loading during calibration. The PTO shaft was held in position by a vice and a meter long beam was inserted into the shaft arms (perpendicular to the shaft length) and loaded statically. The results of this procedure are shown in Figures 6.2.1 and 6.2.2.

4.2.6 Measurement of the Implement Reactive Forces.

The most important part of this phase of evaluation of the power driven disk tiller was to quantify the direction and magnitude of the longitudinal(L) and vertical(V) reactive hitch forces. The component forces measured were: two longitudinal forces (one on each of the lower links), two forces perpendicular to the links in the vertical plane (on each of the lower links) and the compressive/tensile force in the top link, a total of five component forces. Quantification of the longitudinal forces was used to compute the draft and power requirements of the implement and thus provided a basis for energy efficiency performance evaluation. The lift forces gave an indication of the implement's effect on dynamic wheel load and on the tractor's tractive ability. Measurement of the side force was considered infeasible with the three point hitch dynamometer used. The power disk was adjusted such that the lower link chains remained slack during operation

Quantification of these forces was achieved by applying strain gages on a three point hitch dynamometer. A dynamometer similar to that described by Luth (1978) was used. The original lower hinged-end draft links were machined to uniform thickness and width at the hitch points to facilitate the application of strain gages and remove possible strain concentration points brought about by non-uniformity. Strain gages were cemented on the machined surfaces. The top link was cleaned at mid-position and strain gages were configured to respond to compressive and tensile forces only. Great care was taken on installing these transducers to minimize possible damage and to maximize sensitivity, direction and location of gages.

The Wheatstone bridge circuit for each of the component forces measured was made up of four active strain gages (Micro measurement EA-XX-125PC-350) with 350 Ohm resistance and a 10-Volt excitation level (Figure 4.3). The M-coat protective coating system (F-Kit Micro measurement) was used for mechanical protection and water proofing the strain gage bridge circuits. A five-conductor shielded cable transferred the low voltage signal from the transducer to the M1060 high performance signal conditioning amplifier, described previously.

Calibration of the force transducers deserves detailed description, because measurement of reactive forces formed the main thrust of this project and because of the cross sensitivity response of the strain gages brought about by the nonuniform geometric nature of the hinged end links.

The calibration of the three point hitch dynamometer required the application of pure longitudinal or vertical forces on the five transducers individually, while monitoring response of the other gages in either axis. The non-uniform geometric configuration of the

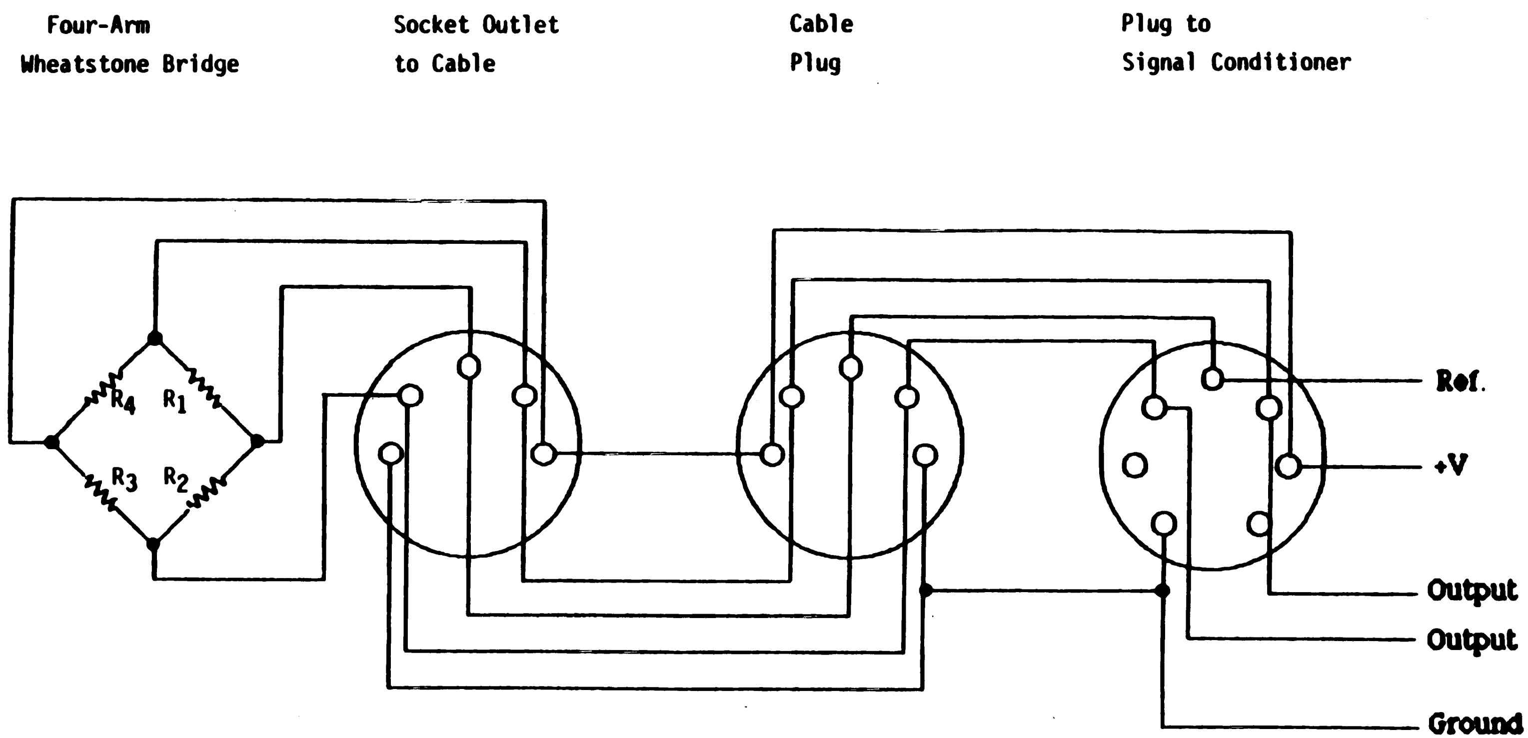


Figure 4.3 Wheatstone Bridge Circuit of the 3-Point-Hitch Dynamometer

hinged-end lower links introduced areas of strain concentration that made it impossible to simulate pure longitudinal or vertical forces without response in either axis(cross sensitivity).

Even under ideal conditions, with uniformly-configured beams and gages accurately-placed about the neutral axes in both the longitudinal and vertical planes, most researchers have only been able to limit the vertical to longitudinal sensitivity ("cross sensitivity ratio") to 10%. In our work, with the hinged-end lower links the ratio was as high as 25%. To correct for this cross sensitivity, the calibration response equations for either the horizontal or vertical forces contained both the horizontal and the vertical axis response voltages. Preliminary field tests on the PTO driven disk tiller indicated that the lower links were held in a consistant position once in operation because of constant tillage depth during each test run. Thus it was not necessary to measure the dynamometer hitch angular position.

The maximum allowable tensile load on each of the links determined from the geometry and material of the lower hinged-end links was 20 000 N. The loading mechanism was set up as shown in Figure 4.4a. The force was applied by retracting a double acting hydraulic cylinder with a load capacity of 45 000 N.

Each lower link was loaded to 16 000 N (3 500 lbs) (tension) in each loading direction in steps of approximately 2 000 N (500 lbs). A Chatillon hydraulic tensiometer type HLC (John Chatillon and Sons), of maximum load, 44 500 N (10 000 lbs) was used to measure the forces.The tensiometer was connected in line, between the link and the loading hydraulic unit.

Since the transducers were essentially linear in their response, strain gage response under compressive loading was assumed to be as

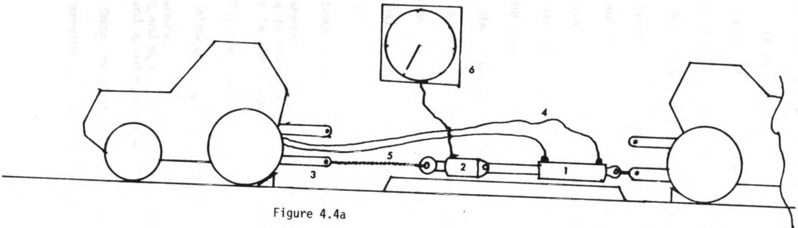


Figure 4.4a

1 - Loading Hydraulic Cylinder
2 - Hydraulic Dynamometer
3 - Lower Link Transducer
4 - Hydraulic Hose Connections
5 - Loading Steel Chains
6 - Loading Scale

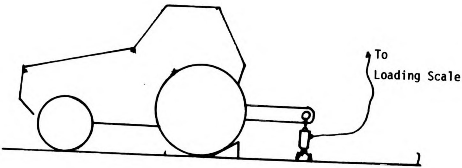


Figure 4.4b

Figure 4.4 Calibration Loading Setup: 4.4a Simulating the Horizontal Forces
4.4b Simulating the Vertical Forces

linear as in tensile loading, thus the top link was loaded in tension only. It was loaded in a similar fashion to the lower links, except the magnitude of the maximum load was reduced to maximum expected field force on that link 8 900 N (2 000 lbs).

For the vertical loading, a metal loading bay imbedded in the laboratory floor was used as shown in figure 4.4b. With the Chatillon hydraulic tensiometer in between the floor support and the links, the vertical load was simulated by actuating the draft control lever (inside the tractor) upwards, insteps of 2 000 N (500 lbs) to 8 900 N (2 000 lbs).

The calibration process was controlled by a program, in the data acquisition system, called "CALIBRATION PROGRAM" (Appendix C). The program recorded the output response voltage at each loading and carried a standard regression analysis. The load recorded was related thus:

Load (lbs) = a + m * voltage

where:
a is the intercept
m is the slope of the response curve.

For the lower links the calibration equation was of the form:

Voltage = $(a_h + m_h$*Horizontal load$)+(a_v + m_v$*Vertical load$)$

where:
a_h and m_h are the intercept and slope in the horizontal axis
and a_v and m_v are the intercept and slope in the vertical axis.

Data related to calibration of the force transducers are provided in Appendix B.5. The calibration equations are listed in Table 6.2.1.

4.3 The Data Acquisition Hardware

The data acquisition system was capable of operating at high speeds, collecting up to 16 channels of data sequentially and storing the data into RANDOM-ACCESS-MEMORY (RAM) space in the microcomputer. The system consisted of an AI13 Analog to Digital (A/D) converter (Interactive Structures Inc.) and a 65C02 microprocessor based microcomputer (Apple IIe, Apple Computer Co.).

The analogue to digital conversion was at the heart of the data acquisition system. It was the interface between the analog and digital domains. Analog signals were sampled, quantized and encoded into digital format. The quality of an A/D converter is specified by :

1. Acquisition time, which is the time required to select a particular analog channel, convert the signal to its corresponding digital value and present the digital value to the computer. Acquisition time reflects the maximum speed of the hardware and it is software controlled.

2. Resolution, which is the smallest analog change that the hardware can detect. For an n bit converter it is given by one half to the power n. The quantizing error associated with the resolution is $\pm$1/2 the least significant bit (LSB).

3. The relative accuracy, which is a function of the linearity of the converter, and is less than $\pm$ 1/2 LSB.

Performance specifications on the AI13 A/D converter are outlined in Appendix B.7.

The 16 channel 12-bit AI13 A/D converter provided software-scaling of signals to any of the 8 full-scale ranges with 0.024% resolution. Each channel was read in 20 micro-seconds with a sample-hold circuit. Figure 4.5 shows the schematic diagram of the A/D converter. The channel number, order, sampling frequency and gain level for each channel were software controlled.

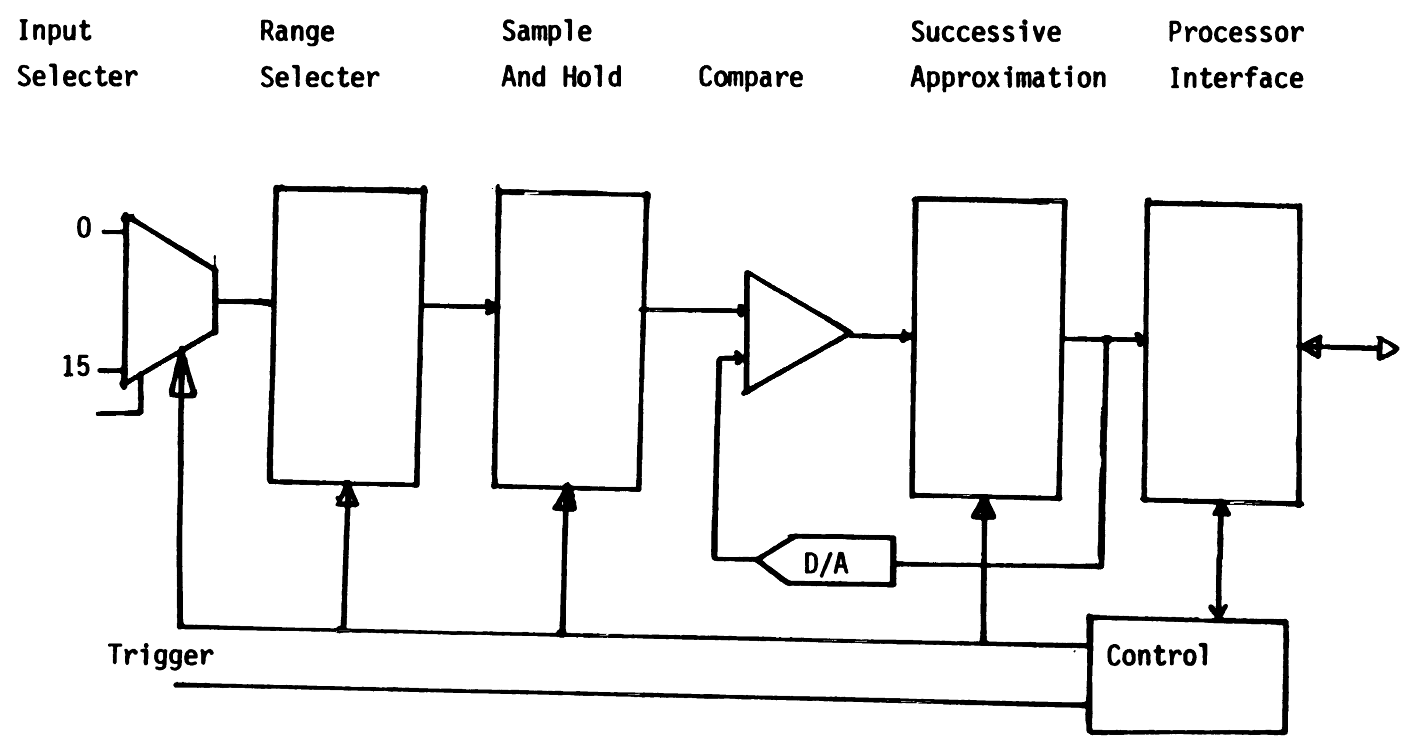


Figure 4.5 Schematic Block Diagram of the Analog To Digital Converter

The system was designed to use two computers, one for collecting data (on-board the tractor, Apple IIe) and the other for data processing (in the office, Apple III). The data-collecting computer had to withstand the the harsh field conditions, be compact and inexpensive. Most important, the data collecting computer had to have a large block of Random-Access-Memory (RAM) to hold the data collected during the test runs and have the ability to dump the collected data onto the disk between test runs. The Apple IIe with its record of functioning well under extremely adverse conditions, (Carnergie, Grinnell and Richardson (1983)), its 64 Kilobytes of RAM, 16K of ROM, plus its peripherals (keyboard, dual disk drive and the 40/80 column screen) provided the versatility required to execute the "RUN" commands. The peripherals allowed the operator to record the collected data on the disk and to check the operational status of the transducers at the end of each test run.

The Apple IIe and the dual disk drive were housed in a fully foam-padded wooden box, with full access to input/output ports to the computer and adequate ventilation. The monitor was placed on top of the wooden box and held in position by elastic bands. The whole unit was securely strapped onto the left side of the tractor window platform by some heavy-duty elastic bands. The tractor cab was sealed shut and kept as dust free as possible.

All the electronic hardware was powered from a 12VDC-120VAC, 60Hz, 500 Watt sinusoidal voltage converter (model 20-500, Venner Corporation, Ohio). No-load voltage was 123.8 VAC with voltage spike at points of maxima and minima (and 120.2VAC at full load) in the waveform when tested in the laboratory. Frequency was constant at 60Hz with or without load. The unit measures 22x24x20cm and has a mass of 7Kg. The unit was thus a reliable power inverter and conveniently small for use in the tractor.

The power source for the inverter was a 12VDC (free-floating ground) battery, housed inside the tractor,behind the operator's seat. For recharging, the battery was connected to the tractor through a double pole, double throw switch. During the data acquisition the battery inside the tractor cab was isolated from the tractor chassis by means of the switch. This was done to ensure purity of the power supplied to the hardware and to effectively prevent any current leakage from the transducers directly attached to the tractor ground potential and isolate any interferrence from the engine rpm fluctuation.

4.4 The Data Collection Software

4.4.1 Theoretical considerations.

Sampling is defined as the act of measuring a continuous function at discrete time intervals (Vandoren, A. (1982)). Sampling soil reactive forces is extremely complex exercise to accomplish, given the random varying nature of the soil. Dynamic soil tillage response signals are of a random type, highly unpredictable at any future time; the signals are best analyzed using statistics and probability concepts.

Average values, instead of instantaneously varying values, represent the desirable research information. The question to be addressed on sampling randomly varying signals is how frequently should these analog signals be sampled to obtain the true average values? Most researchers believe that sampling should be done as frequently as the data acquisition system permits. This can still result in sampling frequencies which are too high or too low. High speed sampling rates load the system and often generate more data than researchers need. On the other end of the scale, inadequate sampling rates can create inaccurate average values for the signals; these inaccuracies are referred to as "ALIASING".

The sampling rate chosen (10 Hz) was controlled by the storage memory of the data acquisition system.The hardware was capable of sampling at higher frequencies than 10 Hz, but sampling any higher would significantly reduce the length of the test runs (i.e. fill the available memory much faster), and in the process generate too large a data set over a statistically insignificantly short test run. Sampling at 10 Hz, also meant that there was minimum time difference in the sequential interrogation of the transducers (as shown in the summary below), thus eliminating any dynamic error in the sampling process.

The AI13 A/D Converter

Selection and sampling time/channel ....6 microseconds
Hold and conversion time/channel...................14 microseconds
Total time/channel..................................20 microseconds
Program running time................................30 microseconds
Time taken to read one channel......................50 microseconds
Time period to complete 10 channels...............500 microseconds
Delay time (computer reading time)...............99.5 milliseconds
Total Acquisition Time (99.5 + 0.5) ms......100milliseconds (0.1s)

The limitation in the system was the RAM. Available storage memory (less the operating system memory) was approximately 34K (RAM), capable of addressing and storing a maximum 7 727 data sets. Operating 10 channels (for the ten variables monitored) allowed 772, truncated to 700 data points per channel and sampling at 10Hz filled the memory in 70 seconds. At the lowest expected ground speed of 2 Km/h (0.56 m/s), the data acquisition system interrogated the sensors every 5.6 cm of forward distance displaced (i.e. 0.56 m/s multiplied by the sampling time of 0.1 s) for a test run 39 m long, which is equal to the time required to fill available memory (70 s) multiplied by the ground speed (0.56 m/s), in every channel. For the other two forward speeds considered ; 4 Km/h and 6 Km/h , the distance sampling intervals were 11.2 cm and 16.67 cm for 78.4 m and 116.7 m test runs respectively.

4.4.2 The Data Acquisition Program.

The program was written in a series of subroutines to retain the flexibility required for a general purpose data acquisition program of this nature.

The data collecting portion of the program was in two parts, each written in a different programming language. Subroutine GETAI13.DELAY (Interactive Structures Inc.) was in machine language. Its main function was to control the conversion of the analog data to their corresponding digital form in the A/D converter. GETAI13.DELAY read and buffered the data in ASCII code. Subroutine AI13.1 written by Mah, M.(Ph. D. candidate, Agricultural Engineering Department, Michigan State University) was in BASIC and served as the interface between the operator and the hardware during the field test runs. Its main fuctions were to provide parameters required by GETAI13.DELAY and to transfer the collected data in RAM to files created in the diskettes. The data transfer operation was executed with the tractor stationary, to avoid data loss on the flimsy diskettes due to vibration.

Subroutine AI13.TEMBO (Mah, M., Michigan State University) was the data processing program, written in BASIC and executed on the Apple III in the office. Data processing was carried out after all field operations had been completed. Its main function was to retrieve the data stored in the diskettes in ASCII code, convert these data into numerical values, execute the required arithmetic operations (conversion of English units to Metric units) and store the data in files for subsequent statistical analysis.

The program was "user friendly", and was designed with great application flexibility. Figure 4.6 shows the global data acquisition program flow chart and Figures 4.7 and 4.8 show the detailed data collection and data processing program flow charts. The program listing is in Appendix C.

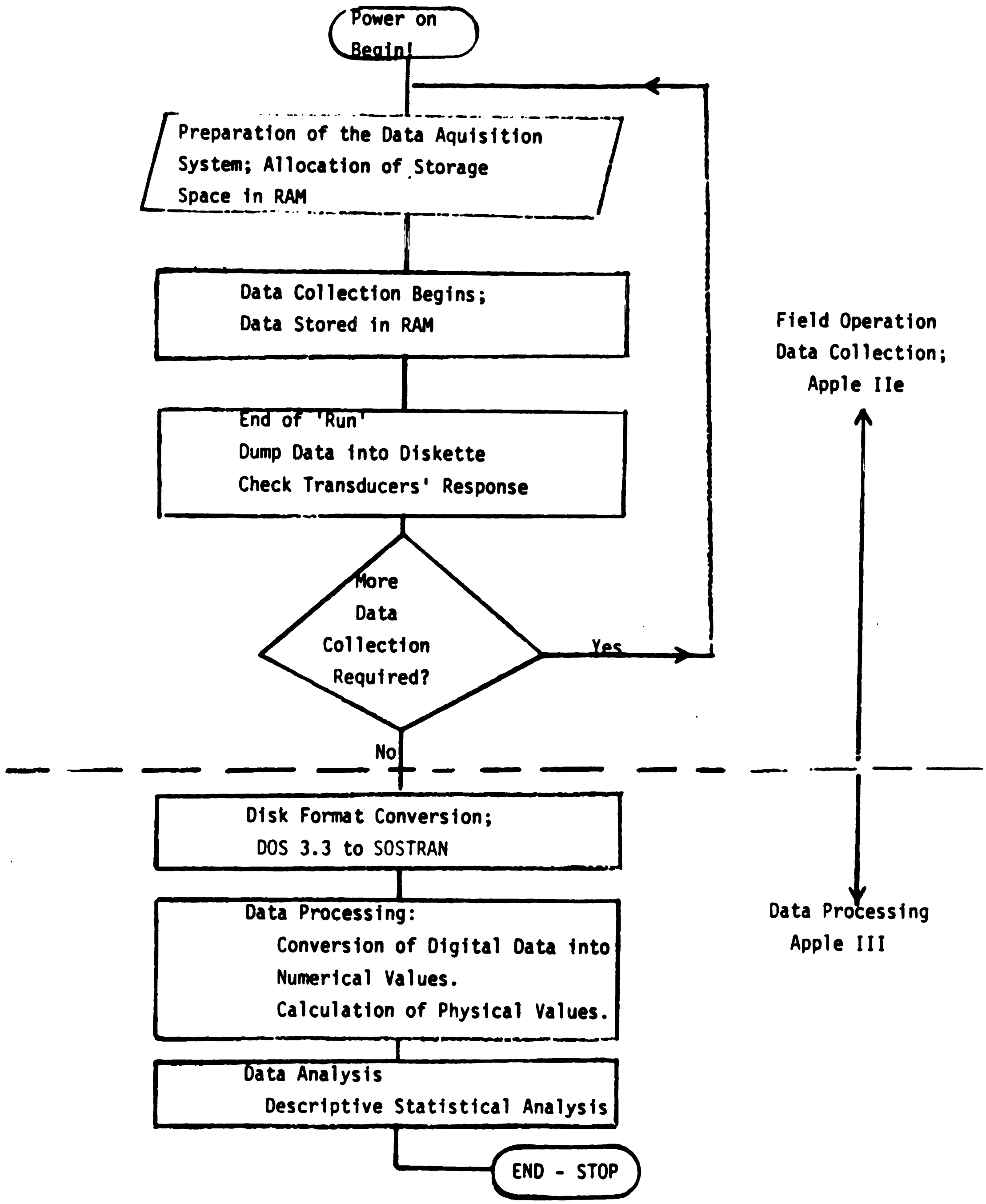


Figure 4.6 Global Flow Chart of the Data Aquistion System Software

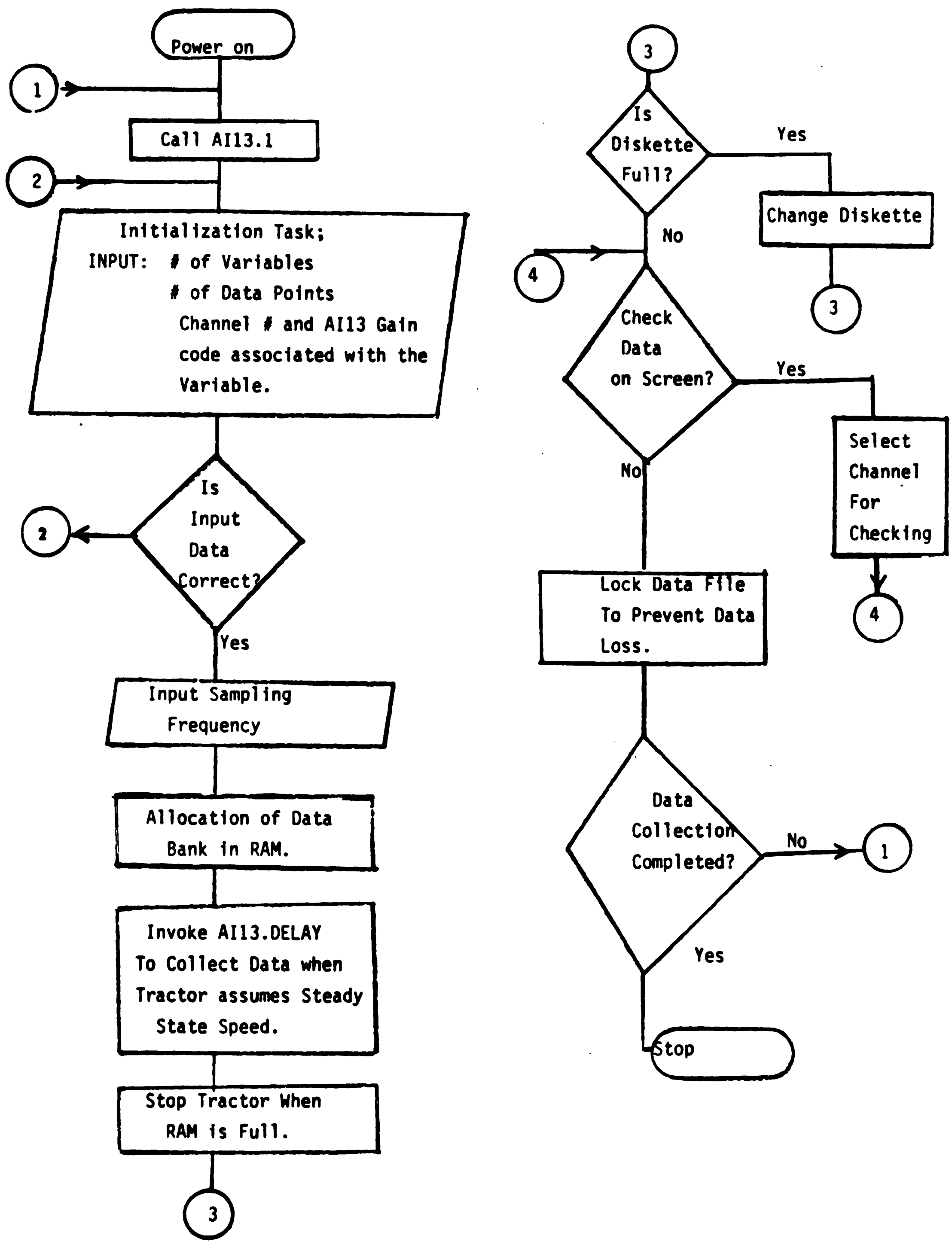


Figure 4.7 Data Collection Program Flow Chart.

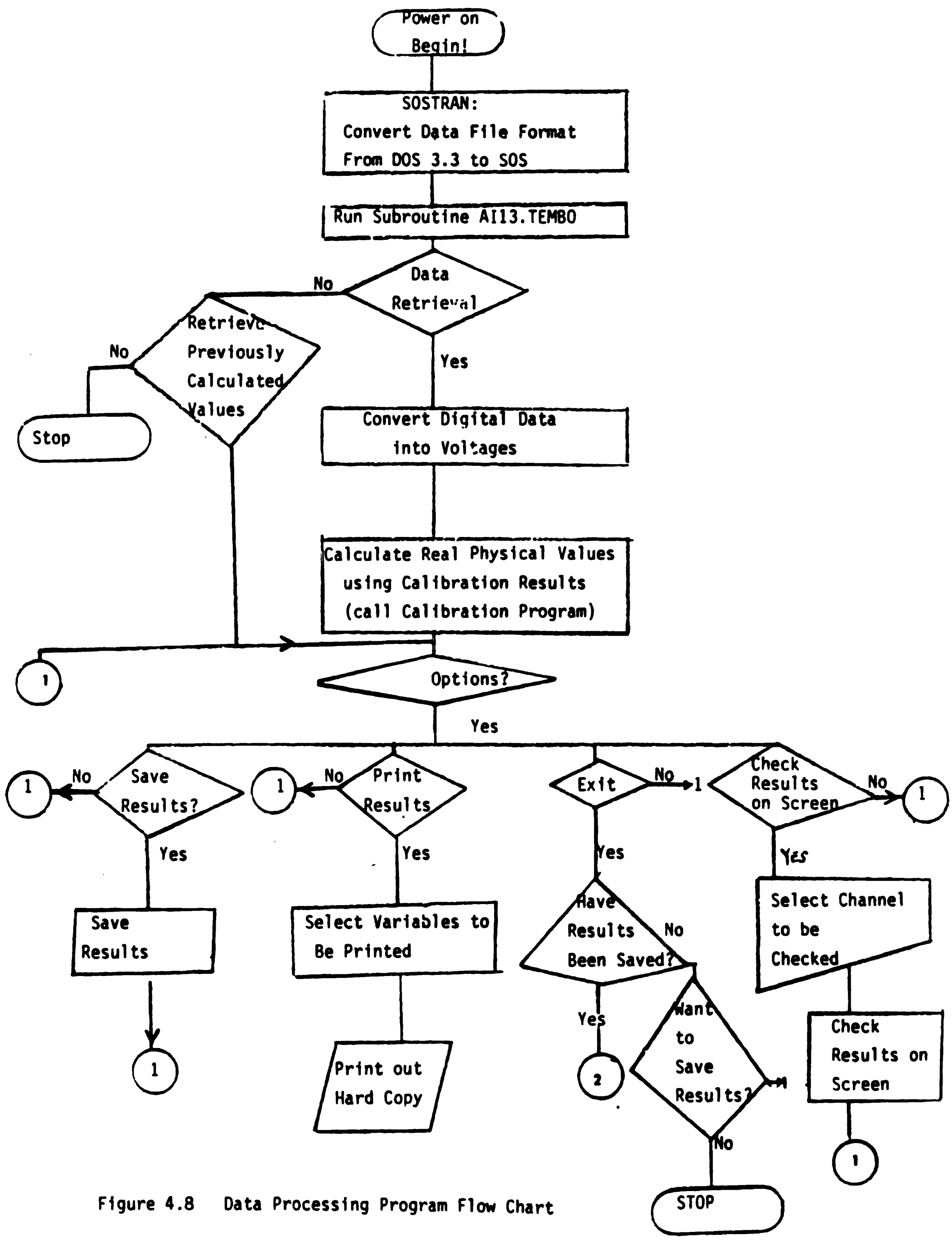


Figure 4.8 Data Processing Program Flow Chart

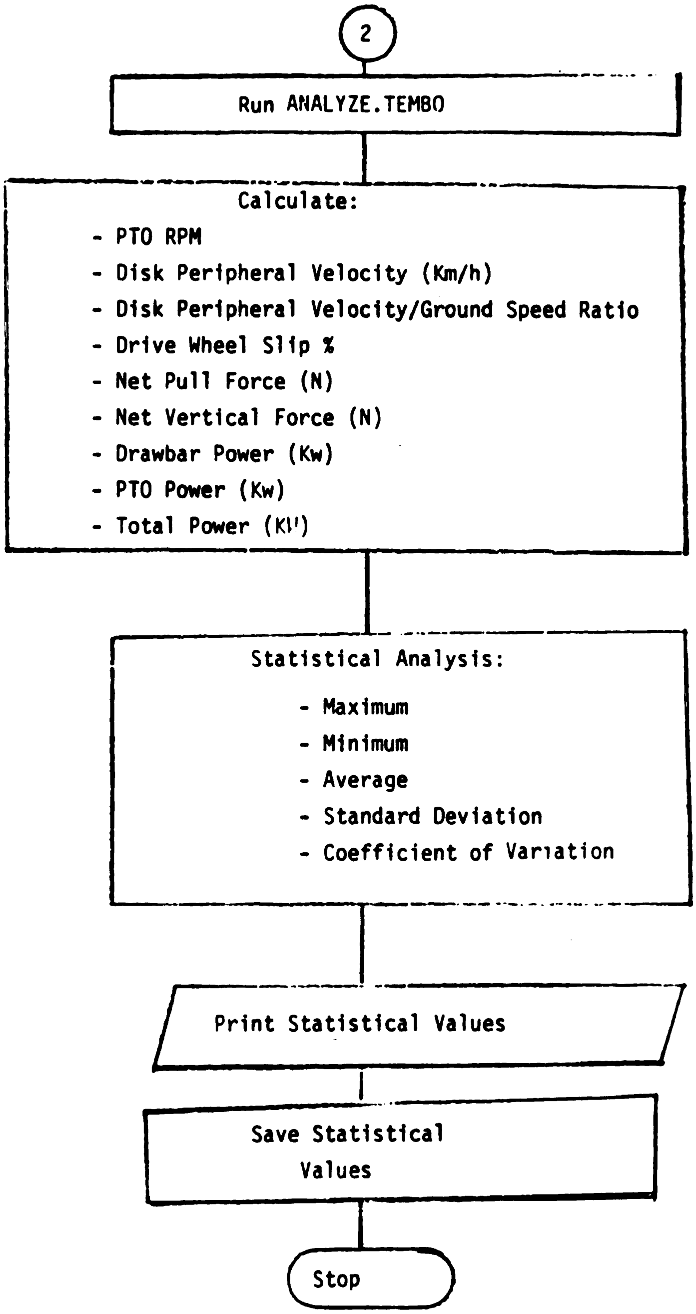


Figure 4.8 (cont.) Data Processing Program Flow Chart

CHAPTER V

EXPERIMENTAL PROCEDURE

5.1 The Test Site.

The field used for field testing the PTO driven disk tiller was adjacent to the Swine Research Facility on the Michigan State University farm; located approximately 5Km South of the main University Campus. The field had been harvested for corn silage and the corn stalks had been cut off at about 30cm above ground. The harvesting operation had involved some field trafficing and some level of compaction was observed, however no soil compaction values were recorded. Furthermore the field was moldboard plowed every fall or spring time, to a depth of approximately 25.4cm (10 inches); deeper than the PTO driven disk tiller was expected to operate. The field was in continuous corn rotation.

The soil was a sandy loam with moisture content of approximately 16% (dry basis), at the time of field testing. The tests were carried out on 16 and 17 October 1985, one week after a long period of rainfall but the field was trafficable. Sixteen percent soil moisture represents an average of 54 soil samples collected randomly over the test area. This soil moisture level was close to field capacity as the engineering and scientific soil properties of the soil indicate in Appendix F.

5.2 Field Variables.

In addition to the ten variables monitored by the data acquisition system, the quality of tillage (residue coverage, soil pulverization and surface roughness) was evaluated qualitatively, and the tillage depth was measured using a steel measuring tape and a straight edge.

The quality of the tillage operation was considered the principal criterion by which farmers judged implement performance. Farmers are mostly concerned about how well an implement accomplishes a desired tillage operation. Their ratio of performance evaluation would be the comparison of actual tillage quality compared to the desired quality. An ideal implement would produce the desired soil surface roughness, surface residue coverage and soil pulverization and have a performace ratio of ONE. Qualitative evaluation of implement performance as outlined above may be considered unscientific, but it must not be ignored as it represents the most practical basis of evaluation at farm level. Indeed the quality of the tillage can be scientifically quantified, however that concept was considered to be beyond the scope of this project.

Tillage depth was not a controlled variable as such, it varied with whatever variable combination was under investigation. Tillage depth measurements were made at the furrow wall (next to the untilled area) with a straight-edge and metric rigid tape. Five measurements were taken over the test run length and averaged.

Quantification of the ten variables monitored by the data acquisition system, provided the basis for scientific implement evaluation that would facilitate an educated selection of energy efficient implement-tractor systems. The field tests were designed to measure the effect of varying ground speed and PTO speed on the PTO driven disk tiller's draft and power requirements and overall field performance. The variables were varied in the following order:

1. The ground speeds (2 Km/h, 4 Km/h and 6 Km/h) at constant pto speeds and soil operating conditions.
2. PTO speeds (540 rpm, 760 rpm and 1000 rpm) at constant ground speeds.

Ground speed selection was guided by the ASAE Agricultural Machinery Management Data (ASAE D230.4) recommendations. PTO speed selection was based on standard PTO shafts (540 rpm and 1000 rpm) and 760 rpm was chosen to replicate similar test procedures used earlier by researchers at Mie University, Japan.

Keeping ground speed constant was achieved through appropriate gear selection and PTO speed through the use of standard PTO shafts(the six spline shaft for 540 rpm at 1900 engine rpm and the twenty-one spline shaft for 1000 rpm at 2060 engine rpm). For 760 rpm PTO speed two tractors were used in tandem. The implement powering tractor at 1565 engine rpm and in "neutral" drive gear position was pulled by another tractor at the preselected constant ground speeds as shown in Figure 5.1. Keeping both PTO and ground speeds at exactly the preselected magnitudes during the test runs was extremely difficult. The results, therefore do not show the exact preselected speeds but approximate values that the operator managed to keep constant.

Each variable combination test run was replicated; for a total of 18 (3 * 3 * 2) test runs, plus one test run at 1000-to-0 PTO speed at a constant ground speed; simulated the powered versus the unpowered disk tiller comparison (a total of 19 runs). The disk blade geometric parameters were kept constant; disk angle was set at 31 degrees and only one set of spherical disks evaluated.

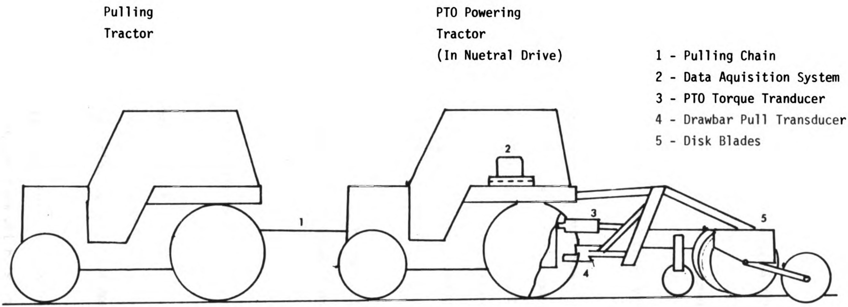


Figure 5.1 Field Test Procedure at 760 RPM PTO Speed

5.3 Method of Data Processing.

Data were processed on the Apple III in the department office. Subroutine AI13.TEMBO retrieved the data (in ASCII code) collected in the field, converted the data into numerical values, executed the required arithmetic operations (conversion of the collected digital data into real physical values) and finally stored the data into output files, ready for statistical analysis.

A specific statistical analysis subroutine, ANALYZE.TEMBO (specific to both the data format and the required statistical analysis) was used. Subroutine ANALYZE.TEMBO provided summary statistics of the nine primary variable measurements plus the calculated variables. The computed performance values were:

1. PTO shaft rpm
2. Net horizontal forces in each lower link (draft)
3. Net vertical forces in each lower link (lift)
4. Net force in the top link
5. Drive wheel slip
6. Drawbar power requirements
7. PTO power requirements
8. Total power requirements
9. Peripheral disk velocity and
10. Peripheral disk velocity to ground speed ratio.

Performance equations for calculating the above variables are given in Appendix A, in the form which is used in the program.

Summary statistics of both the measured and derived parameters included maximum, minimum, average, standard deviation and coefficient of variation values. True average values have provided the most acceptable research data and meaningful basis for comparative performance evaluation in tillage studies in the past; thus average values were used for the graphical analysis in the evaluation of the PTO driven disk tiller.

CHAPTER VI

RESULTS AND DISCUSSION

6.1 The Equipment

The data acquisition system which was described in Chapter Four functioned well. The Apple IIe worked reliably in the mild weather conditions; ambient temperatures were between 4 and 21 degrees Celsius, humidity at approximately 60 % and the air was not dusty. From observations made by Carnergie et al.(1983) on similar equipment, functional problems could be anticipated in the hot, humid and dusty weather conditions. Measures are being taken to ensure that the data acquisition system does not fail when operating under these more adverse environmental conditions.

The transducers were able to monitor their respective parameters and the output signals were successfully processed by the data acquisition system.

6.2 Accuracy in the Measurements

The objective of the research was to measure with acceptable accuracy, the draft and power requirements of the PTO driven disk tiller. The accuracy, repeatability and reliability of the measurements became critical factors in the study. No reliability problems were experienced with the overall data acquisition system. Accuracy and repeatability of measurements were determined through thorough laboratory calibration procedures. Figures 6.2.1 and 6.2.2 show the

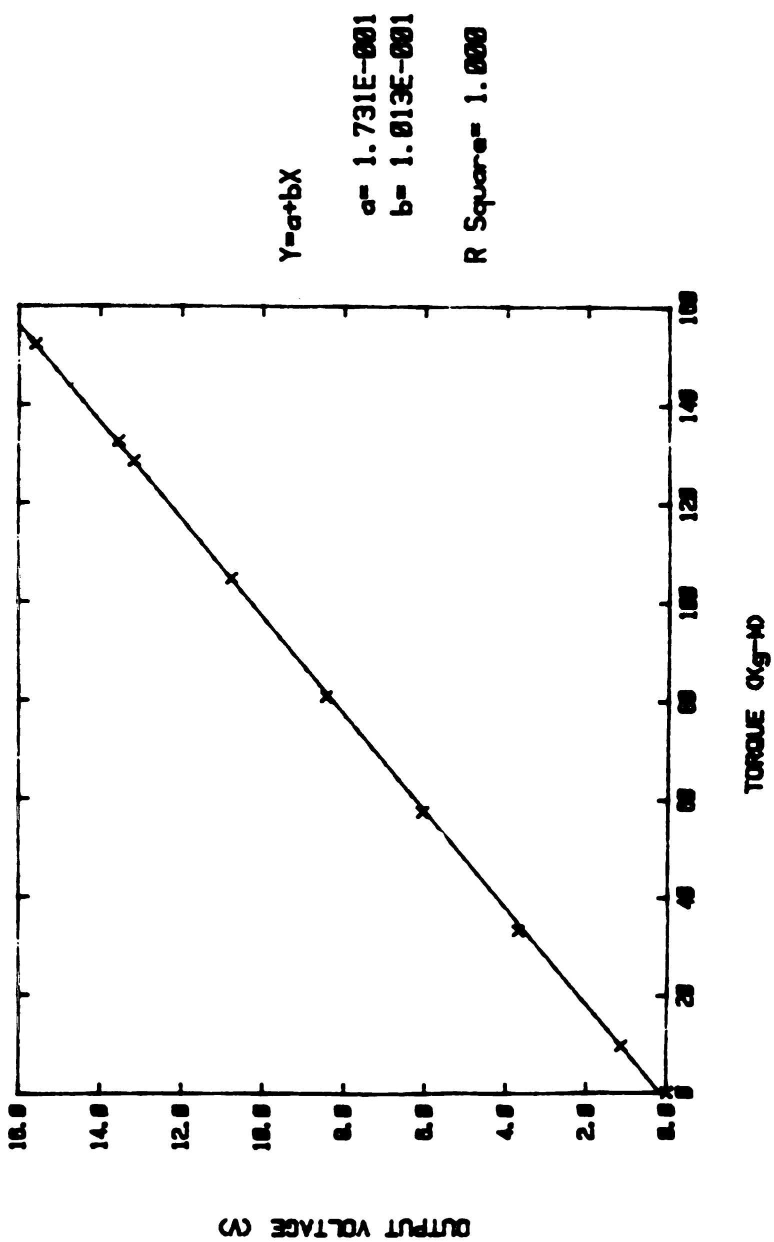


Figure 6.2.1 Torque meter Calibration Response Curve (Before Field Tests)

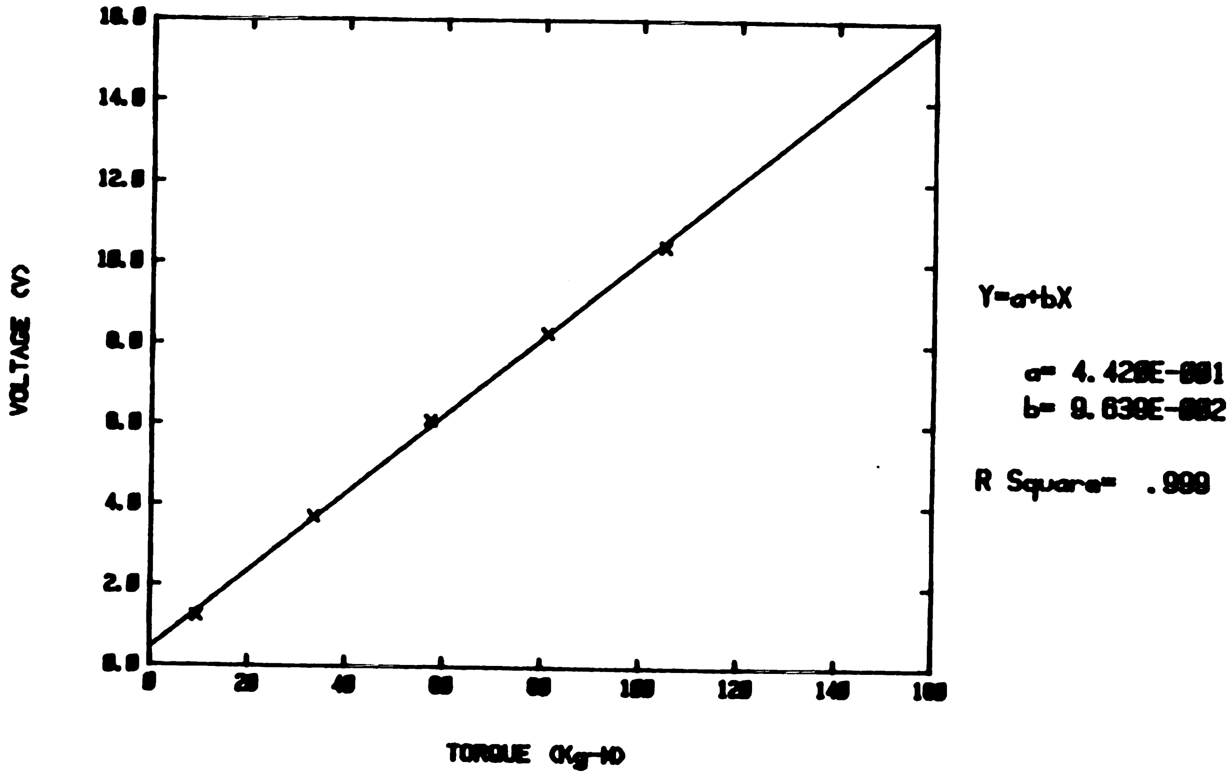


Figure 6.2.2 Torque meter Calibration Response Curve (After Field Tests)

typical calibration response curves, before and after the field test respectively. Figure 6.2.3 shows the hysteresis effect from strain gage response due to repeated static loading and unloading. Hysteresis was considered to be insignificant in all the calibration measurements made. Table 6.2.1 lists the calibration response equations and the coefficient of determination (R-SQUARED) values of each of the measured parameters. Also in Table 6.2.1, the forces and the torque (in the second column) are are represented in lbs and Kg-m respectively, because these are units in which the calibration was carried out. The graphical presentation of calibration process was also in these (lbs and Kg-m) units. However these units were converted to standard Metric units in the processing software, thus Tables 6.3.1 and 6.3.2 and the graphs are all presented in Metric units.

Since our transducers were essentially linear, the specification of nonlinearity was therefore an equivalent specification of overall inaccuracy. The accuracy of the measurements made was thus based on the calibration procedures used and/or the transducer manufacturers' quoted accuracies whenever these values were provided. Calibration procedures used were guided by the recommendation of using calibration equipment theoretically ten times more accurate than the transducer being calibrated. As a result the overall system error for the data acquisition system was less than 0.05 %.

The first row of Table 6.3.1 shows the relative percent error between the measured and the derived calibration parameters. Derived calibration values were calculated using a standard mathematical procedure (Deoblin 1984). Calibration data and manufacturers specifications for the transducers are given in Appendix B.

Channel #	Variable	Calibration Response Equation	R^2(Main Effect)	R^2(Cross Effect)
1	Rear Right Horizontal Pull (lbs)	$mV = -46.412 + 0.156\ F_H^{*} + 179.5 - 0.437\ F_v$	0.996	0.950
2	Left Horizontal Pull (lbs)	$mV = -27.496 - 0.066\ F_H + 12.84 - 0.220\ F_v$	0.997	0.996
3	Right Vertical Force (lbs)	$mV = 2.757 - 0.103\ F_H + 30.374 - 1.113\ F_v$	0.9995	0.985
4	Left Vertical Force (lbs)	$mV = -4.068 - 0.021\ F_H + 21.158 + 0.725\ F_v$	0.996	0.995
5	Top Link Force (lbs)	lbs = 11.82 + 3455 * Volts	0.996	
6	Engine (Rpm)	Hz = 1.3038 + 33.5905 * Volts	0.999	
7	Radar (Km/hr)	Hz = 1.10881 + 99.2926 * Volts	0.999	
8	Rear Wheel (Km/hr)	Hz = -0.5958 + 24.9019 * Volts	0.999	
9	Front Wheel (Km/hr)	Hz = -0.6452 + 25.33407 * Volts	0.999	
10	Torque (Kg-m)	Nm = 17.088 + 789.73 * Volts	0.999	

* F_H - Horizontal Component Force

F_v - Vertical Component Force

Table 6.2.1 Calibration Response Equations and R^2 values as a measure of Linearity.

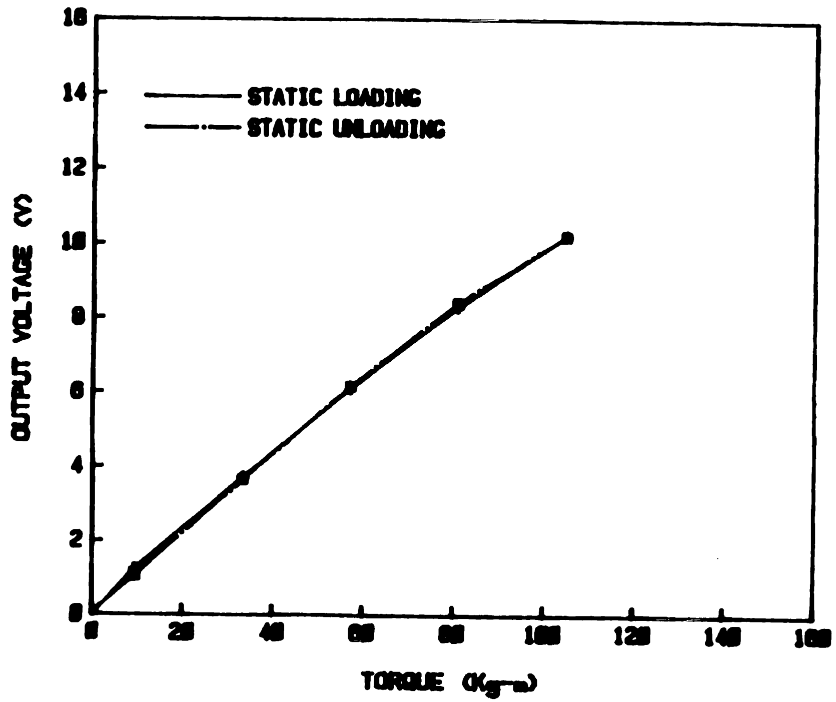


Figure 6.2.3 Hysterisis Effect on Torquemeter Response During Calibration

6.3 The Results

Table 6.3.1 shows the average values of the data from the overall statistical analysis of 19 test runs extracted from Appendix D. Appendix A lists all the performance equations used in the calculation of the parameters listed in Appendix D. Appendix E lists a complete printout of data from one typical test run (700 data points per channel, 7 000 data points total).

Detailed comparisons were based on average values as shown in Tables 6.3.1 and 6.3.2. Maximum and minimum values of individual variables occurred at different times during the test run, therefore comparisons and/or calculations based on the maximum or minimum values would be incorrect. Consequently the graphical analysis provided in this section was based on the average values listed in Tables 6.3.1 and 6.3.2.

6.3.1 Ground Speed: Draft and Power Requirements

Increasing ground speed at constant PTO speed:

1. Reduced draft significantly; a 200 % increase in ground speed (at 1000 rpm PTO) reduced draft by 75 % (Figure 6.3.1).
2. Reduced tillage depth; a 100 % increase in ground speed (at 1000 rpm PTO) resulted in tillage depth reduction of 33 % (Figure 6.3.2).
3. Increased the lift effect of the implement on the three point hitch, i.e. the lift forces changed their orientation from vertically downwards (+325 N at 2 Km/h) to vertically upwards (- 311 N at 5.6 Km/h) at 540 rpm pto speed (Figure 6.3.3).

The dynamic reorientation of the implement lift forces on the three point hitch was a factor contributing to the reduction of both tillage depth and draft as ground speed increased. The literature reviewed suggested that side draft (a parameter not measured in this

Cal. Error % / 'Run'	Ground Speed (Km/hr)	Tillage Depth (cm)	*Net Draft (N)	°Net Lift Force (N)	Torque (Nm)	PTO speed (rpm)	(a) PDV Km/hr	(b) PDV/GS	Dr. wheel slip (%)	Drawbar Power (Kw)	PTO Power (Kw)	Total Power (Kw)
	±1.11	±1.33	±5	±5	±2	±0.1	±0.1	±1.11	- 5.00	±5.5	±2	±5.9
1.	1.86	21.6	12550	+325	476	555	14.3	7.7	8.2	6.5	27.7	34.2
✓ 2.	1.82	21.6	11940	-165	428	562	14.5	7.8	9.5	6.10	25.2	31.2
3.	3.89	19.1	5556	-52	391	558	14.4	3.7	11.7	6.0	22.9	28.8
4.	3.97	19.1	8960	73	435	557	14.4	3.6	10.6	9.9	25.5	35.4
5.	5.62	14.0	*2730	-312	411	558	14.4	2.6	11.4	4.2	24.0	28.2
6.	5.74	12.7	-2577	-312	411	558	14.4	2.5	11.8	4.1	23.9	19.8
7.	1.93	26.7	15240	156	408	1026	26.5	13.7	12.9	8.2	43.8	52.0
8.	1.99	30.5	14675	307	406	1019	26.3	13.2	9.6	8.1	43.3	51.4
9.	4.21	21.6	6479	163	402	1016	26.2	6.2	12.3	7.6	42.7	50.3
10.	3.87	21.6	5436	-217	376	995	25.7	6.7	12.8	5.8	39.1	45.0
11.	6.12	17.8	2724	-91	424	1030	26.6	4.4	13.5	4.6	45.7	50.4
12.	6.31	17.8	1366	-353	479	1037	26.8	4.2	9.1	2.4	52.0	54.4
13.												
14.	2.78	19.1	5975	-424	385	782	20.2	7.3	6.4	4.6	31.5	36.1
15.	5.76	15.0	2054	-408	412	785	20.2	3.5	5.1	3.3	33.8	37.1
16.	5.79	12.7	2557	-352	411	789	20.4	3.5	5.2	4.1	34.0	38.0
17.	7.73	12.7	535	-417	424	782	20.2	2.6	5.3	1.1	34.7	35.9
18.	7.52	12.7	-652	-479	458	784	20.2	2.6	4.9	1.5	38.4	37.0
19.	3.91	5.1	10911	-1101	0	0	≈3.9	≈1	19.6	11.9	0	11.9

✓ All even # 'Runs' are replicates.
* - ve Draft: Implement is 'pushing' on the tractor hitch; +ve is implement pull on tractor hitch.
° - ve Lift force: Implement is 'pushing' tractor hitch vertically up, +ve hitch is pushing implement down.
a PDV: Peripheral Disk Velocity
b PDV/GS ratio is Peripheral Disk Velocity to Ground Speed Ratio

Table 6.3.1 Summary of PTO Driven Disk Tiller Performance

'Run'	Ground Speed (Km/hr)	Tillage Depth(cm)	PTO Speed (Rpm)	Corrected Drive Wheel Slip (%)	SP.DBP (Kw/cm)	SP.PTOP (Kw/cm)	SP. Total Power (Kw/cm)
1.	1.86	21.6	555	2.8	0.30	1.28	1.58
2.	1.82	21.6	562	4.1	0.28	1.17	1.45
3.	3.89	19.1	558	6.4	0.31	1.20	1.51
4.	3.97	19.1	559	5.2	0.52	1.34	1.86
5.	5.62	14.0	558	6.1	0.30	1.72	2.02
6.	5.74	12.7	558	6.5	-0.32	1.88	1.56
7.	1.93	26.7	1026	7.5	0.31	1.64	1.95
8.	1.99	30.5	1019	4.2	0.27	1.42	1.68
9.	4.21	21.6	1017	6.9	0.35	1.98	2.33
10.	3.87	21.6	995	12.5	0.27	1.81	2.08
11.	6.12	17.8	1030	8.1	0.26	2.57	2.83
12.	6.31	17.8	1037	3.8	0.15	2.92	3.05
13.							
14.	2.78	19.1	782	0	0.24	1.65	1.90
15.	5.76	15.2	785	0	0.22	2.22	2.43
16.	5.40	12.7	789	0	0.23	2.68	2.99
17.	7.73	12.7	782	0	0.09	2.74	2.83
18.	7.52	12.7	784	0	-0.12	3.02	2.91
19.	3.91	5.1	0	0	2.34	0	2.34

SP = Specific

Table 6.3.2 Specific Power(Kw/cm) Requirements for the PTO Driven Disk Tiller research) increased with ground speed and was a significant factor in the reduction of tillage depth and the poor performance of driven disks at higher ground speeds. Perhaps this finding should now be seriously considered in future research in order to gain a clearer understanding of force reactions with respect to tillage depth. The reorientation of the lift forces from positively upward acting to negatively downward acting forces was also thought to be a significant factor in the increase of drive wheel slip with increasing ground speed, by reducing traction (as the vertical lift forces increased negatively).

Figure 6.3.3 shows the lift force at 760 rpm was constantly pushing up on the three point hitch with an average force of -417 N. This confirms the observation that tillage depth variation was significantly influenced by the lift force. As the lift force remained constant so did the tillage depth. It is however not clear as to what caused this condition (negative lift force reaction); the test procedure employed at 760 rpm PTO speed or the 760 rpm PTO speed itself.

Increasing ground speed had no significant effect on PTO torque requirements as shown in Figure 6.3.4. The high torque value of 476 N-m at 540 rpm could have been due to a clay type soil strip encountered for the length of that particular test run.

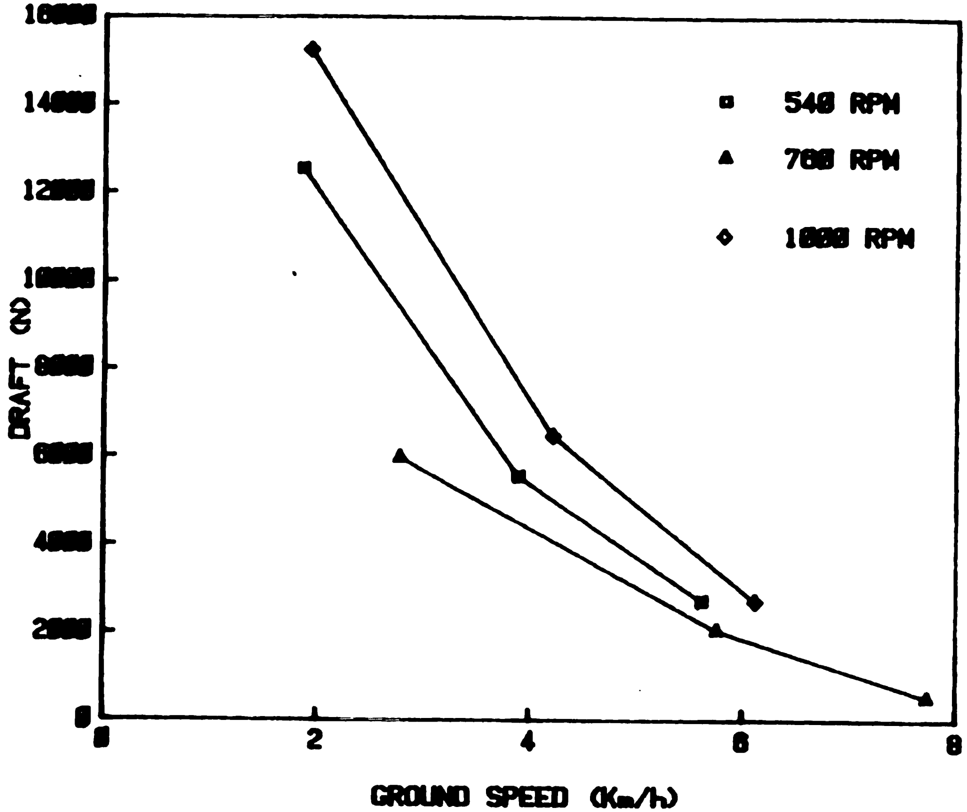


Figure 6.3.1 Effect of Ground Speed on Draft

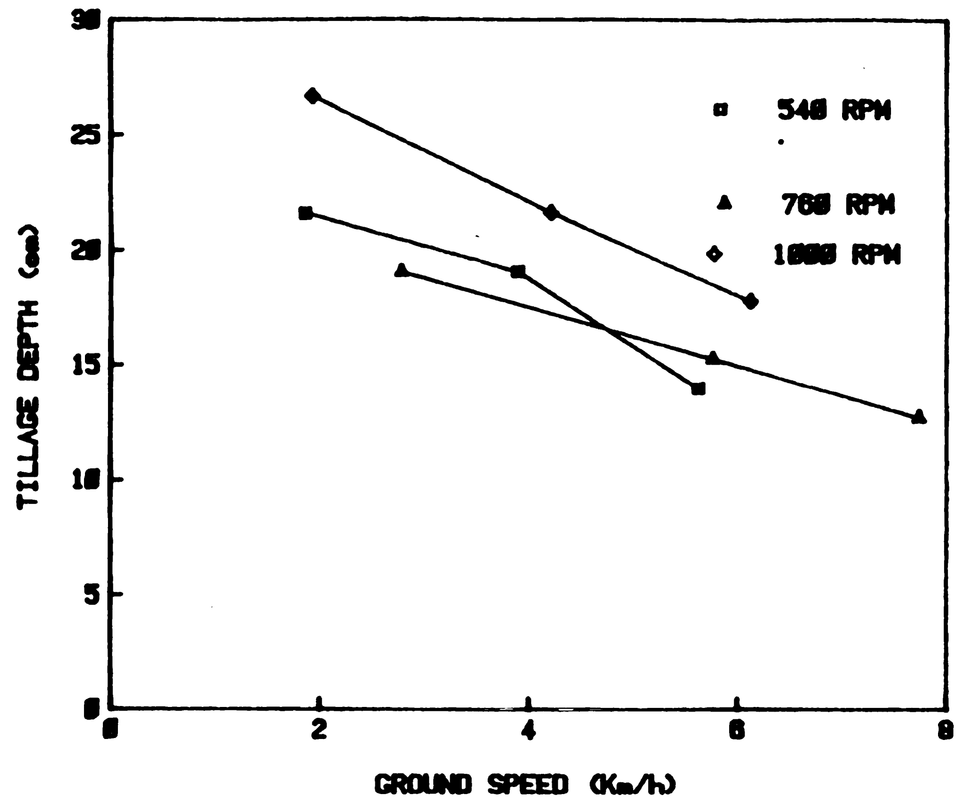


Figure 6.3.2 Effect of Ground Speed on Tillage Depth

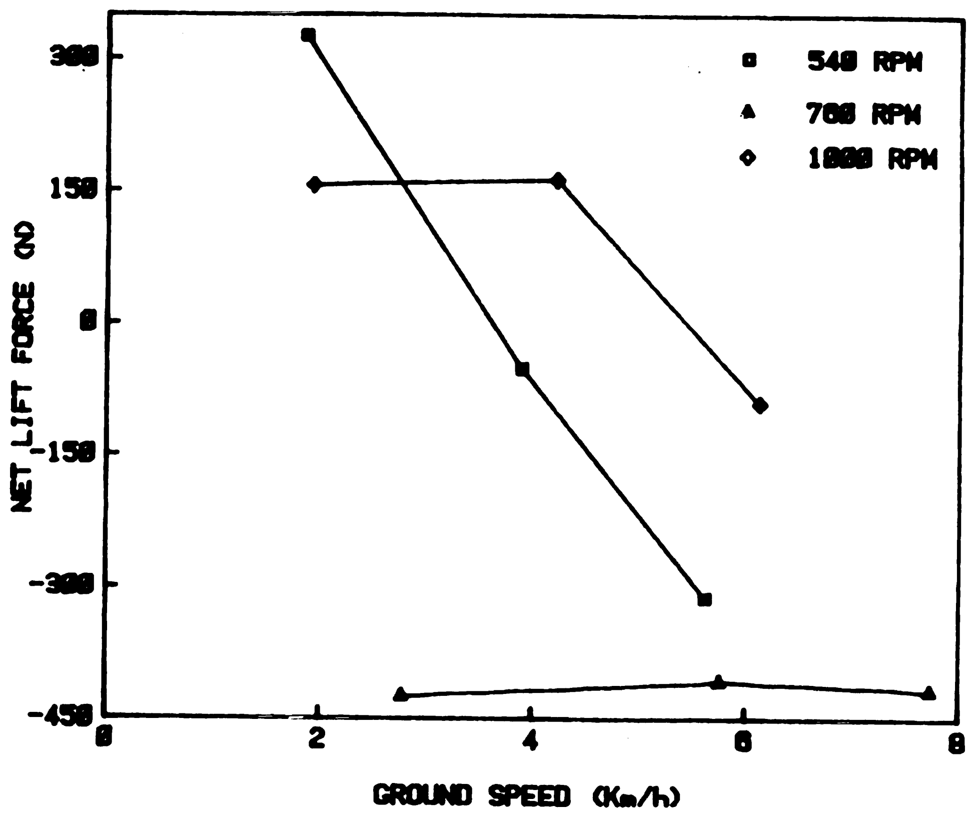


Figure 6.3.3 Implement Vertical Reaction on the 3-Point-Hitch to Ground Speed

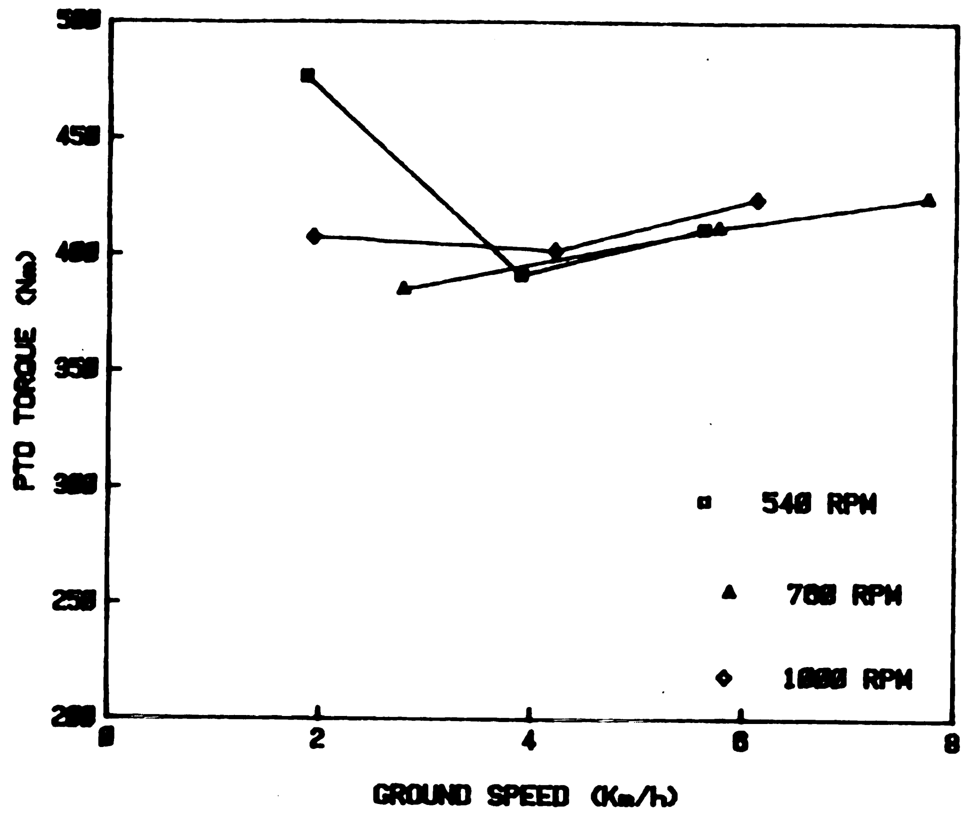


Figure 6.3.4 Effect of Ground Speed on PTO Torque of the PTO Driven Disk Tiller

6.3.2 PTO Speed: Drawbar Power and PTO Power Requirements

Increasing PTO speed:

1. Had little effect on PTO torque; torque remained nearly constant at approximately 420 N-m as PTO speed increased (Figure 6.3.5).

2. Decreased drawbar power requirement sharply by 73% (from 4.24 Kw at 555 rpm to 1.13 Kw at 783 rpm), then increased as sharply and by the same magnitude from 783 rpm to 1024 rpm at constant ground speed of approximately 7.75 Km/h, as shown in Figure 7.3.6. This defined the point of minimum drawbar power at 783 rpm (a peripheral disk velocity of 20.2 Km/h) and ground speed of 7.75 Km/h; a peripheral disk velocity to ground speed (pdv/gs) ratio of approximately 2.5 (Figure 6.3.7).

3. Increased PTO power requirements proportionately; doubling PTO speed, doubled PTO power, as shown in Figure 6.3.8. This was logically expected as PTO torque had remained fairly constant with increasing PTO speed.

4. Increased the total power requirements almost proportionately, see Figure 6.3.9.

Total power was defined as the sum of the drawbar power requirements and the PTO power requirements. Increasing ground speed had little effect on total power requirements.

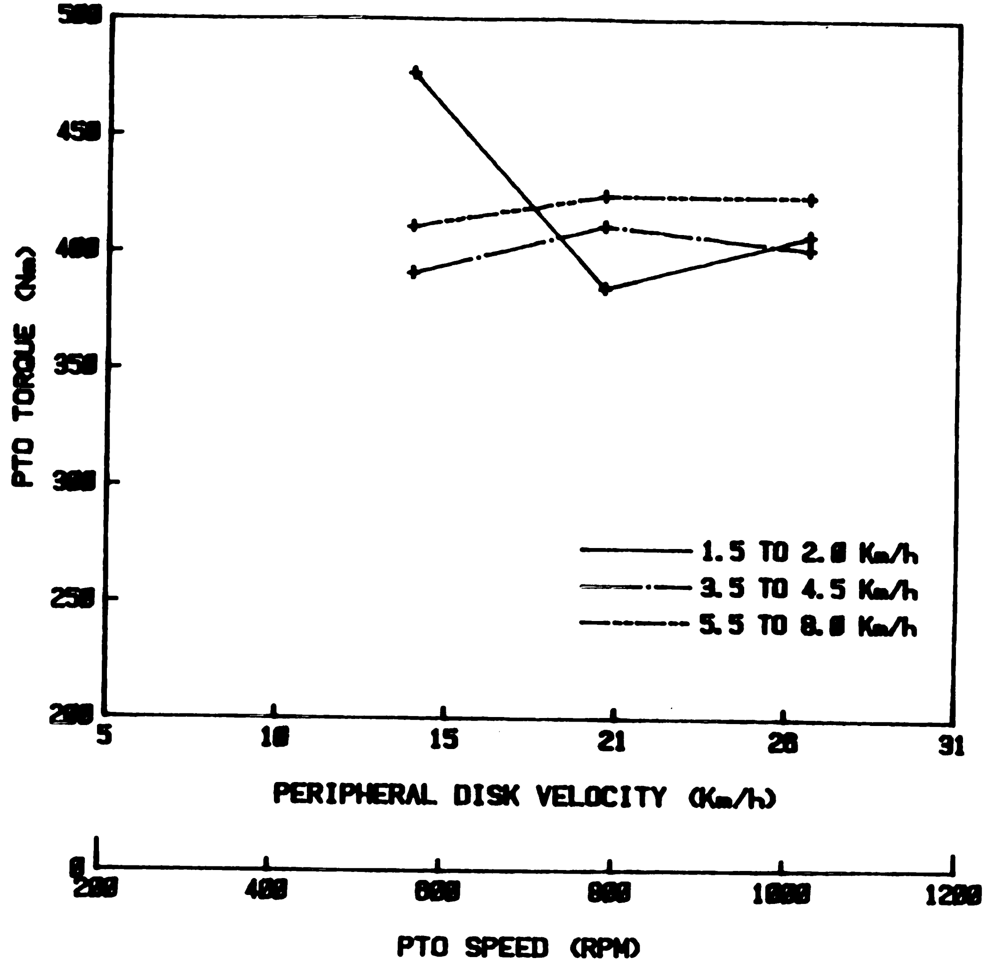


Figure 6.3.5 Effect of PTO Speed (Peripheral Disk Velocity) on PTO Torque

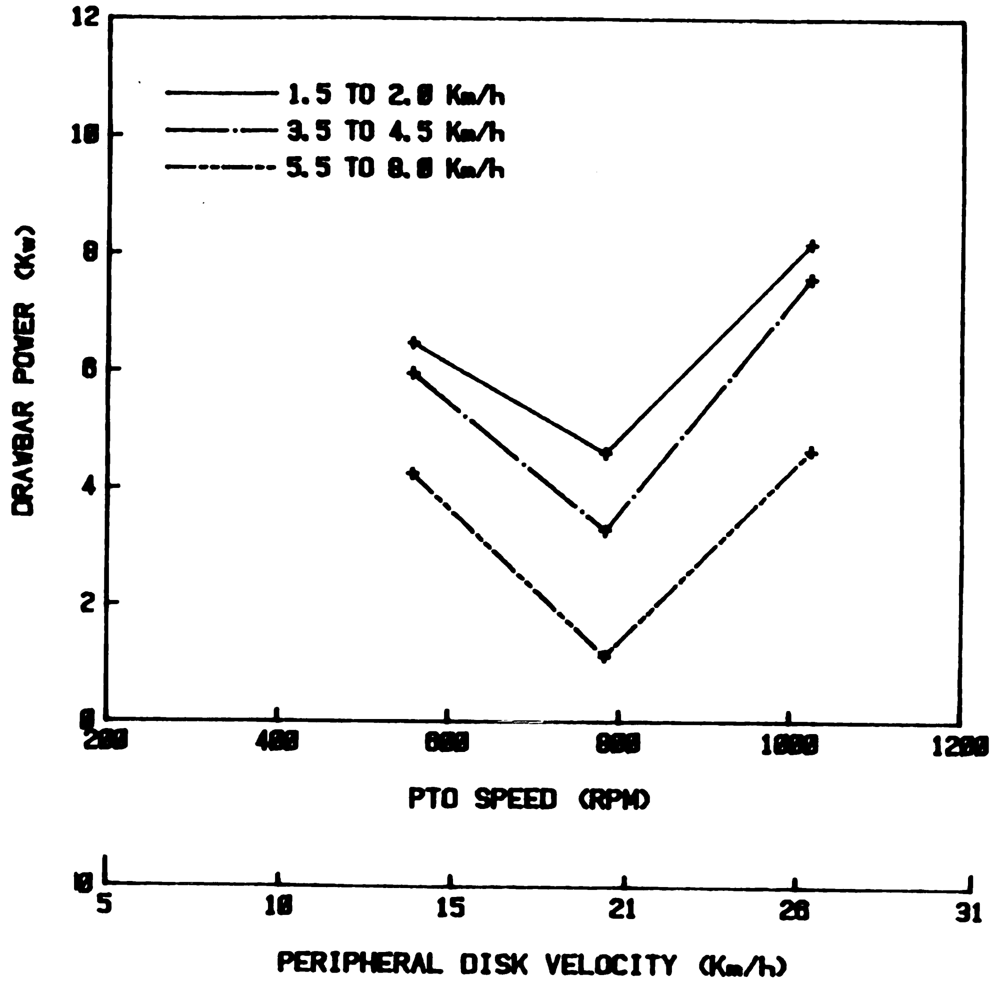


Figure 6.3.6 Effect of PTO Speed (Peripheral Disk Velocity) on Drawbar Power Requirements

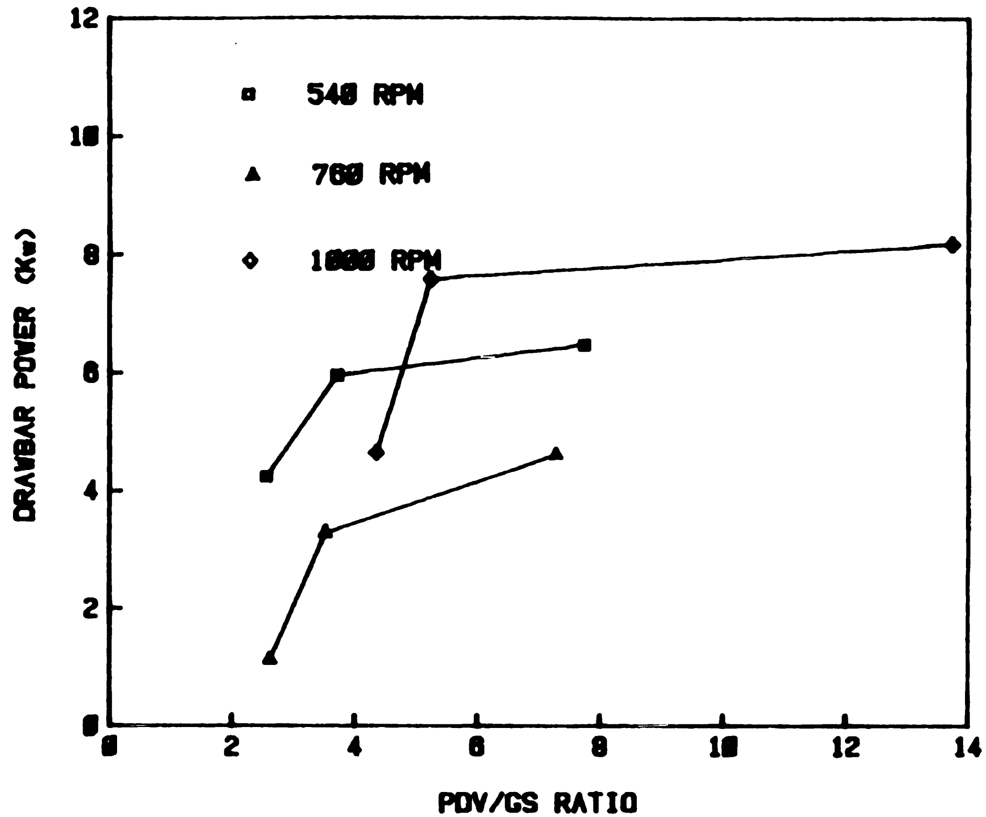


Figure 6.3.7 Drawbar Power Requirements as a Function of Peripheral Disk Velocity to Ground Speed (pdv/gs) Ratio

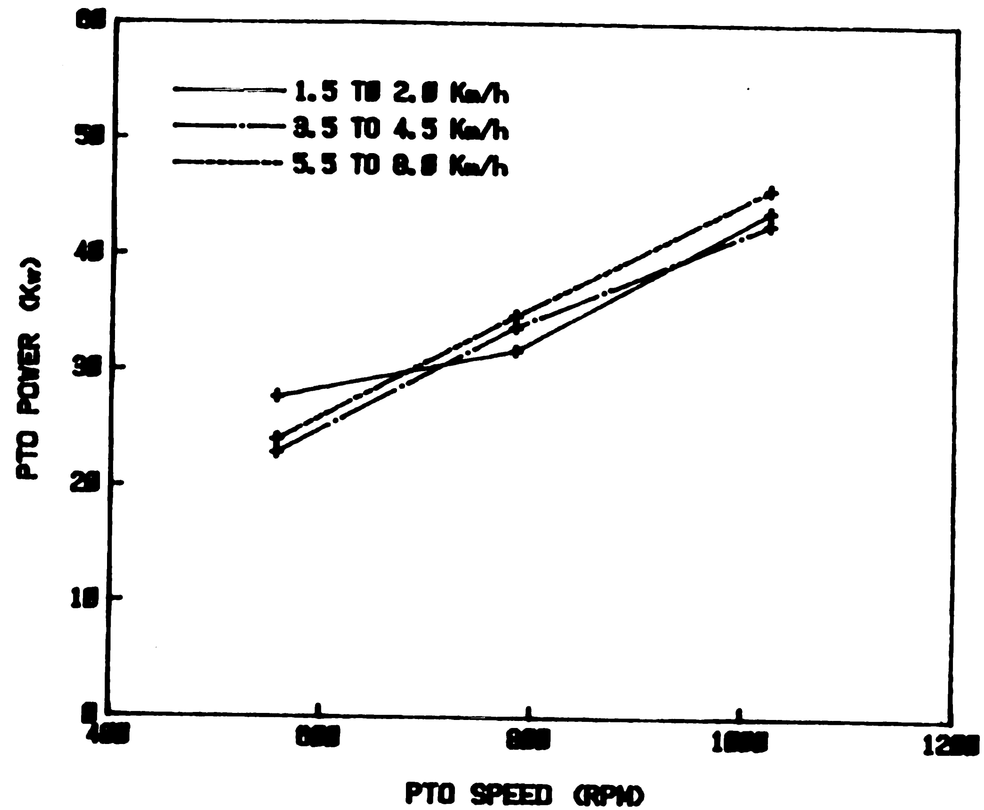


Figure 6.3.8 Effect of PTO Speed and Ground Speed on PTO Power Requirements of the PTO Driven Disk Tiller

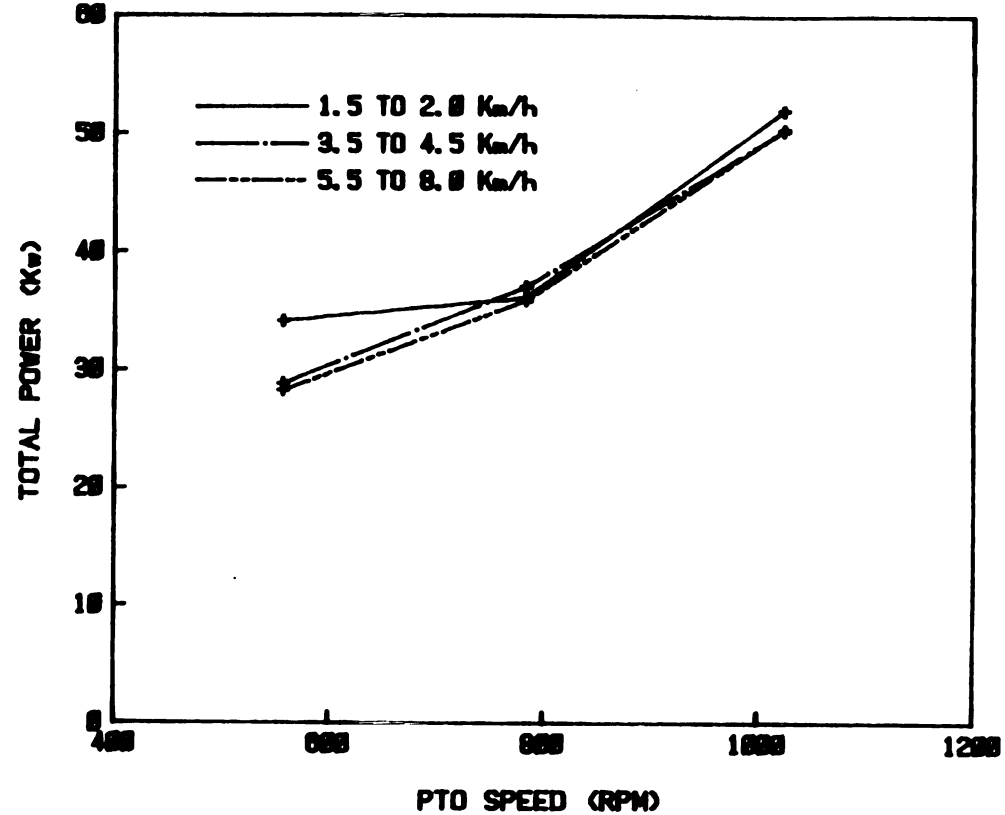


Figure 6.3.9 Effect of PTO Speed and Ground Speed on Total Power Requirements of the PTO Driven Disk Tiller

6.3.3 Power Components: Drawbar Power, PTO Power and Total Power.

Figure 6.3.10 shows the available power components as they were transferred to the PTO driven disk tiller from the engine. Increasing ground speed at constant PTO speed , i.e. lowering the pdv/gs ratio:

1. Decreased drawbar power requirements; the lowest value of drawbar power of 1.13 Kw occurred at a pdv/gs ratio of 2.5,
2. Increased the PTO power requirements to a maximum value of 34.8 Kw at the same pdv/gs ratio of 2.5; total power was 35.9 Kw.

These changes are only significant in relating drawbar power to PTO power with respect to the pdv/gs ratio. The pdv/gs ratio of 2.5 is a divergent point; drawbar power drops to its minimum value while PTO power increases to its maximum value.

Equally important, shown in Figure 6.3.10 was the split into the respective forms of the total available power to the PTO driven disk tiller; 97% of the total power was transferred through the PTO and 3% was drawbar power. Power was proportioned nearly the same at 540 rpm and 1000 rpm.

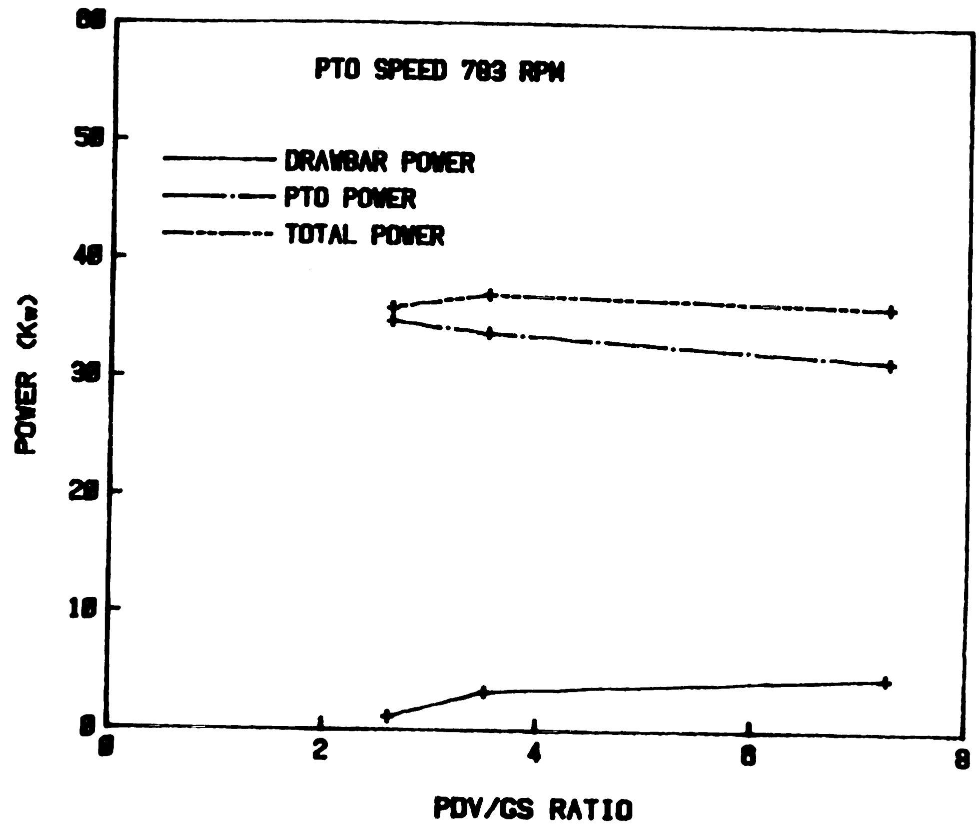


Figure 6.3.10 Drawbar Power, PTO Power and Total Power Requirements as Functions of the Peripheral Disk Velocity to Ground Speed Ratio

6.3.4 Specific Power Requirements

Tillage depth was an uncontrolled parameter in the field tests and it influenced the power requirements of the PTO driven disk tiller. Relating ground speed and PTO speed to specific power (Kw/cm) effectively eliminates the variability of these parameters brought about by the variation in depth. Specific power is defined as the power required to manipulate the soil per unit depth. Normally, specific power is expressed as power required per unit area, however in this study, specific power was expressed in Kw/cm form because the effective width of the PTO disk tiller was kept constant at 200 cm during the tests.

Figure 6.3.11 relates ground speed to specific drawbar power. As the ground speed increased specific drawbar power decreased. This may have occurred because less energy was required to break and invert the loose top soil than it was to till soil at the firm lower layers. Thus, at lower ground speed (where the implement was deep in the soil), there was greater demand of energy per centimeter of soil depth

Figure 6.3.12 shows that the most efficient drawbar power requirement point occurred at a pdv/gs ratio of 2.5. Any deviation from this point either way increased the specific drawbar power requirements. Increasing the peripheral disk velocity from 20.2 Km/h to 26.6 Km/h (a 23% increase), increased the specific drawbar power requirements 150%. Decreasing the peripheral disk velocity by 29% increased specific drawbar power requirements by 200% at 7.75 Km/h ground speed.

The increases in specific drawbar power (from the flexion point) were gentler at lower ground speeds (2 to 4 Km/h) than they were at the

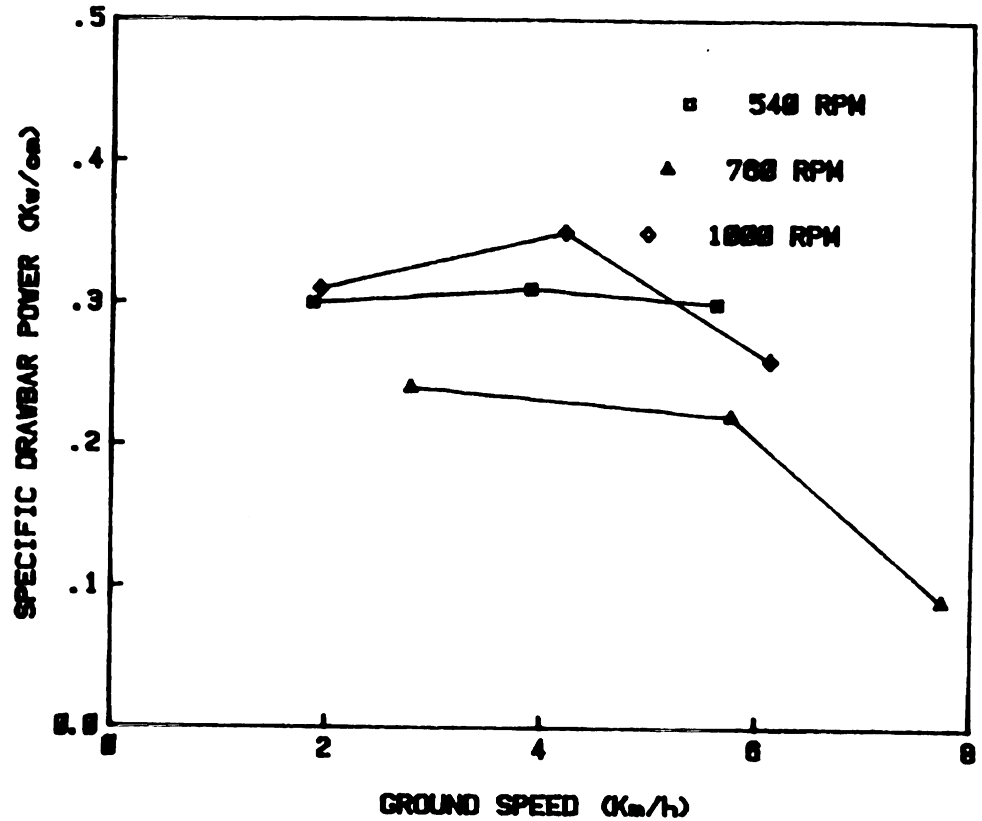


Figure 6.3.11 Effect of Ground Speed on Specific Drawbar Power Requirements

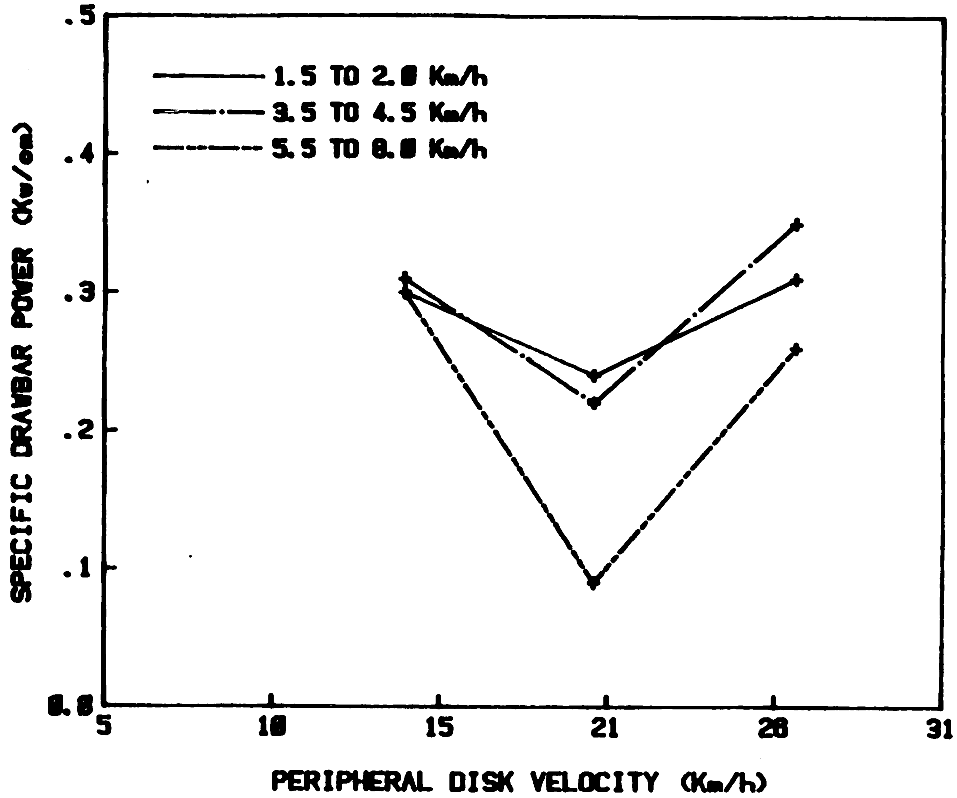


Figure 6.3.12 Specific Drawbar Power Requirement as a Function of Peripheral Disk Velocity

higher ground speeds (5 to 8 Km/h). The gentle gradient in specific drawbar power at the lower speeds may be related to the minimal variation in the vertical forces reactive push downward(+), with a larger magnitude on the 3-point-hitch dynamometer.

Specific PTO power increased with both PTO speed and ground speed, as shown in Figure 6.3.13. The pattern of increase varied at different PTO speeds. The general trend was upward.

Increases in both ground speed and PTO speed meant more soil (volume) was manipulated in one form or another per unit time, thus greater power was required per unit tillage depth.

Total specific power is defined as the sum of the specific drawbar power and specific PTO power in this discussion. Total specific power increased with both the ground speed and PTO speed (see Figure 6.3.14). Increasing PTO speed increased total specific power sharply to a peak value at 783 rpm, then decreased gently with increasing PTO speed.

There was greater pulverization of the soil with increasing ground speed, hence the increase in total specific power.

As ground speed was increased, a larger percentage of the soil being tilled was the loose top soil, thus specific drawbar power tended to decrease with increasing ground speed. However, the total volume of the soil manipulated per unit time at a given PTO speed increased with ground speed, thus increasing specific PTO power. Specific PTO power increased at a higher rate than the decrease in specific drawbar, resulting in an overall increase in specific total power with increasing ground speed as shown in Figure 6.3.15. At 5.75 Km/h, where specific drawbar power decreased steeply and specific PTO power increased sharply; specific drawbar power constituted only 9% of the total specific power and specific PTO power constituted 91% of the

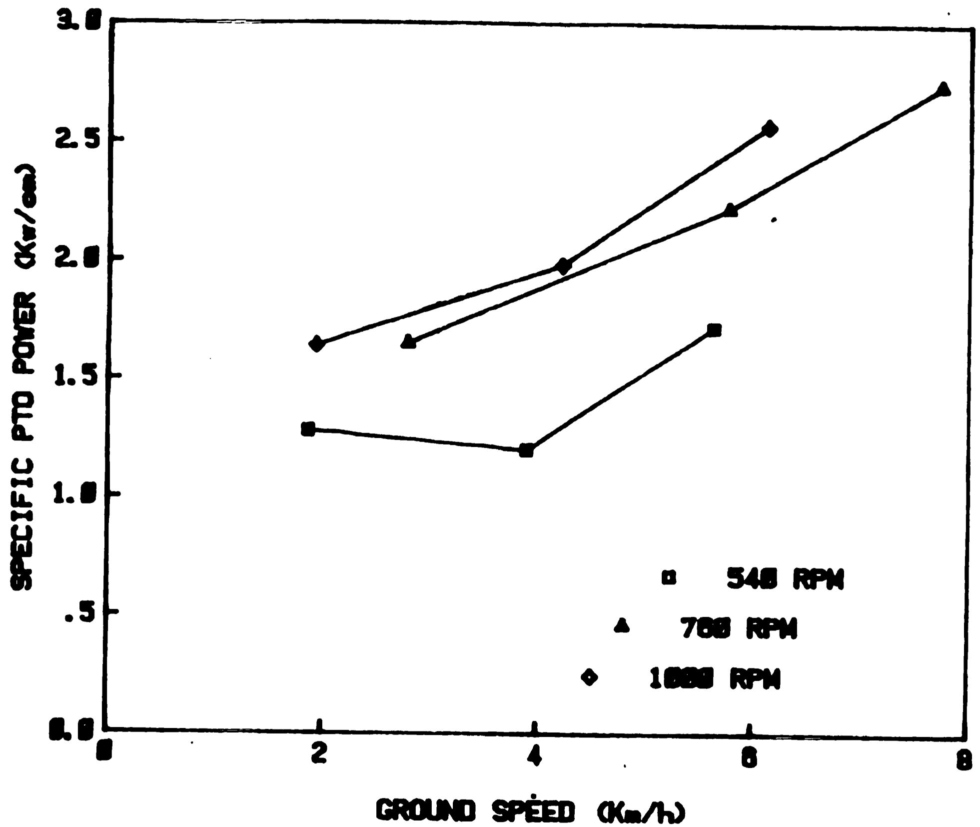


Figure 6.3.13 Effect of Ground Speed on Specific PTO Power Requirements

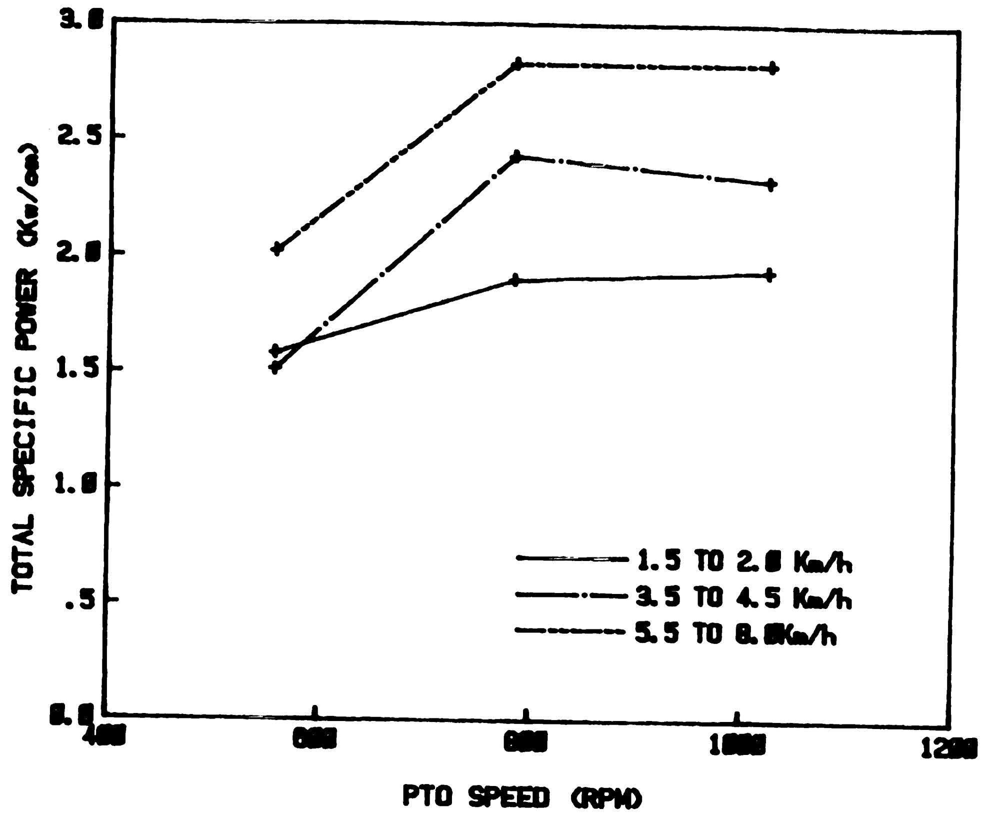


Figure 6.3.14 Total Specific Power as a Function of PTO Speed

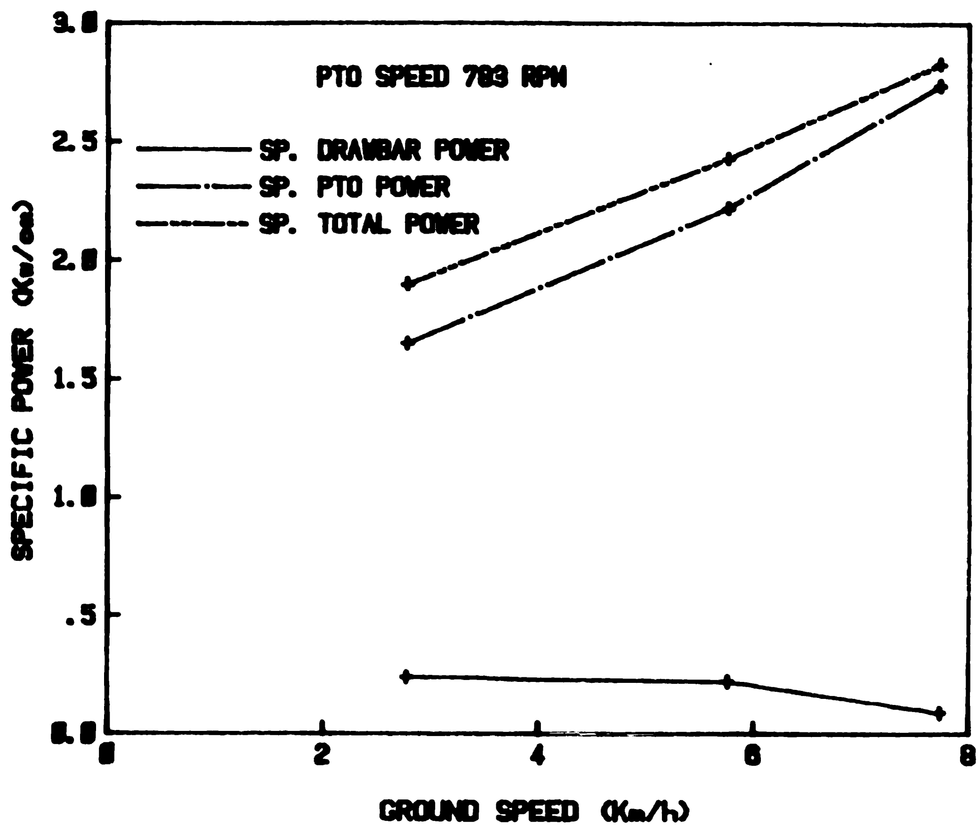


Figure 6.3.15 Specific Drawbar Power, Specific PTO Power and Specific Total Power as Functions of Ground Speed

total specific power.

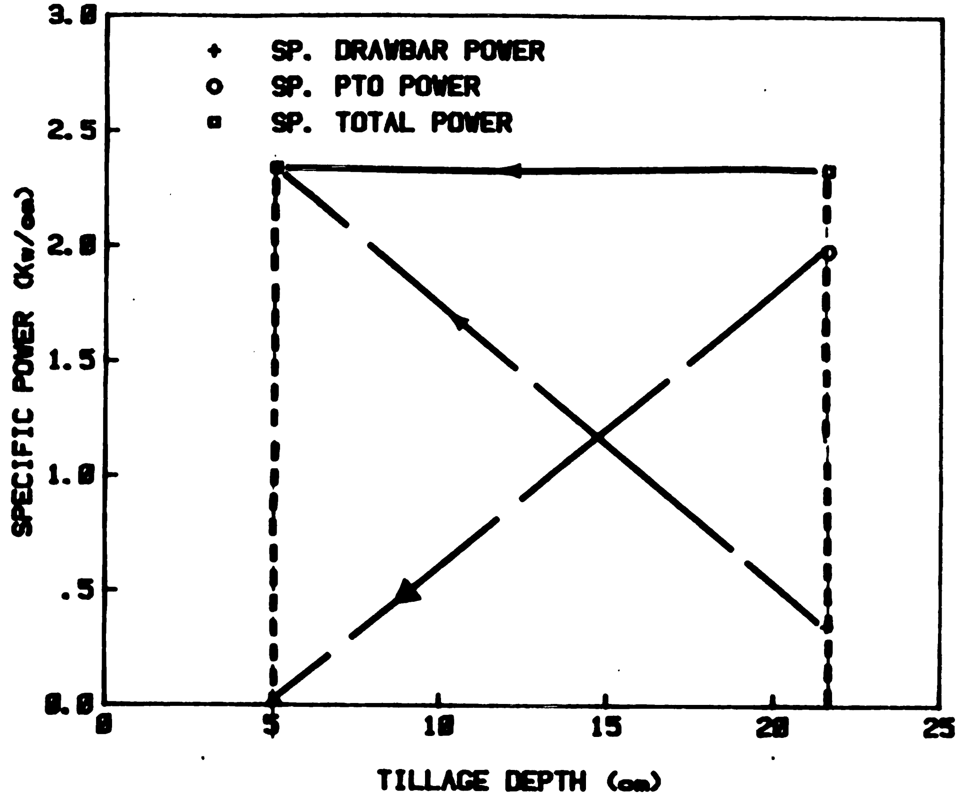
Thus with the PTO driven disk tiller, a large percentage of the available power is transferred to the implement through the power-take-off drive shaft. The PTO drive shaft is a more efficient energy route than the traction route.

What does this mean to implement design engineers and to the farmers? Figure 6.3.16 shows the specific power components in the powered (1000 rpm) and unpowered state (PTO disengaged) of the power driven disk tiller. During the field tests the tractor PTO shaft was disengaged midway through a test run to simulate a free rolling disk plow of the same size and mass. From this test:

1. Tillage depth decreased from 21.6 cm to 5.1 cm at constant ground speed; a decrease in tillage depth of 76 %.
2. Specific drawbar power increased from 0.35 Kw/cm to 2.34 Kw/cm; an increase of 569 %.
3. Specific PTO power dropped from 1.98 Kw/cm to 0.
4. Total specific power increased from 2.33 to 2.34 Kw/cm; a 0.43% increase of total power utilized per cm of tillage depth.

From these results it appears as if the energy savings made by transferring the available power from the engine to the implement through the PTO drive shaft are insignificant; total specific power was the same in the powered state as it was in the unpowered state.

Figure 6.3.16 is based on Table 6.3.2 which lists the calculated specific power requirements of the power disk. From this table, total specific power was 15 % greater for the powered state at 760 rpm than it was for the unpowered (0 rpm). A sizable reduction (32%) in total specific power was attainable at 540 rpm when compared to the unpowered state; the reduction may even be greater than 32% (if one corrects for the effect of tillage depth). Thus, 540 rpm offered the greatest



PTO RPM = 0 PTO RPM = 1000 RPM

Figure 6.3.16 Specific Power Components in the Powered State vs the Unpowered State (PTO Disengaged) savings in energy utilization. However, the questions still remain;

1. Are these energy savings significantly large to warrant implement production of the current design or are design modifications likely to yield even greater energy savings?
2. Is the quality of the tillage operation under the reported conditions, likely to meet the farmers' desired tillage performance criteria?

From an engineering perspective, there appears to be no significant savings in total energy utilization brought about by transferring power from the engine to the implement through the PTO shaft at the higher PTO speeds; i.e. 760 rpm and 1 000 rpm. Savings made in specific drawbar power at the higher PTO speeds are essentially insignificant when compared with increases in total specific power brought about by increases in specific PTO power (PTO speed). However at 540 rpm the savings attainable in specific drawbar power were considered significant; a factor farmers would capitalize on. The PTO driven disk tiller is a power implement and should be evaluated on the basis of the total specific power used. On that basis alone, perhaps more data covering a wider spectrum of environmental, operational and economic factors must be collected before any conclusive statements can be made. Getzlaff et al. (1959), when faced with similar findings, concluded that the 30% reduction in drawbar power brought about by "powering" was insignificant when compared with an almost 120% increase in total power requirements. The concept of a powered disk was then shelved for both technical and economic reasons at that time. A decade and a half later Young (1975) in his field study of a hydraulically powered disk plow, the DynaTil, came up with similar results (to Getzlaff et al.) but ignored the technical considerations in favor of greater on-the-go controllability of the tillage operation. In his conclusion, he argued that a low cost, efficient mechanical drive (which he recommended), and the better tillage operation produced by the passage of a powered disk tiller when compared with free rolling disk tiller, made the powered disk plow a better implement for the farmer.

From the farmers' perspective, this innovation has its benefits, especially when compared with the unpowered state of the same implement. The cutting ability of powered disk (without ballast) in wet soil conditions means that the farmers might use smaller size tractors (capitalizing on the 32% total specific power savings attainable only at 540 rpm). Penetration becomes a problem in very dry soil conditions. Data from our preliminary tests in the summer of 1984 highlight this problem (Figure 6.3.17). In this situation the costs of the powered disk outweigh the benefits as:

1. Ballasting to aid the cutting ability might be counter productive, increasing drawbar requirements sharply and
2. Increasing PTO speed to aid the cutting ability would increase total power requirements significantly, as the results indicate.

In general, the implement performs very well in friable soil conditions. The purpose of a tillage implement is to modify an undesired soil condition into a condition that best serves the farmer's intended use of the soil. Residue coverage, surface roughness and soil pulverization improved with increases in PTO speed over the 3 to 5 Km/h ground speed range. Soil throw increased with increases in ground speed. At lower ground speeds the power disk merely slices the soil layer with minimum inversion.

When plowing at a ground speed of 3 to 5 Km/h and at 1000 rpm PTO speed, tilth considered ideal for Spring planting was attainable. That

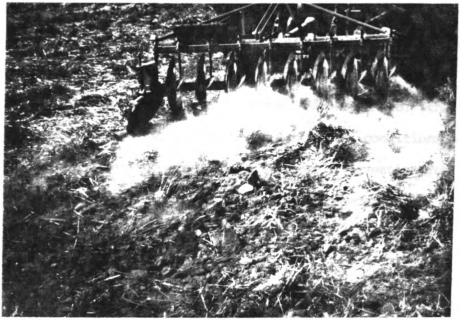


Figure 6.3.17 PTO Driven Disk Tiller Performance in Dry Soil Conditions; Penetration Impared

tilth, however, would not be suitable for Fall tillage as excessive soil pulverization leaves the soil clods smaller than necessary (Figure 6.3.18). Michigan farmers rely on the weathering effect of the winter season with freezing and thawing to reduce soil clod size. Within the same ground speed range, 540 rpm PTO speed, produced the type of clod size that would be most ideal for Fall tillage.

Disking at 3 to 5 Km/h and at a PTO speed of 760 rpm, produced the most ideal tilth for any season. The tillage depth was approximately 16 cm, the soil pulverization was adequate (not excessive), and the mulch incorporation was appropriate. Under this process, however, a second pass with a backward inclined tine would be needed before planting.(Figure 6.3.19)

Extensive comparative performance evaluation of the PTO driven disk tiller over a wide range of physical conditions needs to be conducted. The shortcomings of this phase of investigation is perhaps the lack of emphasis on the qualitative performance.

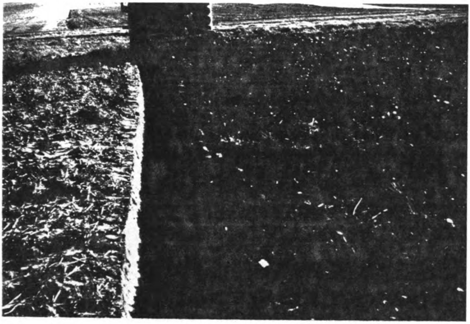


Figure 6.3.18 Excessive Soil Pulverization With Complete Mulch Inversion at 1000 RPM

Figure 6.3.19 PTO Driven Disk Tiller Performance in Friable Soil Conditions

CHAPTER VII

CONCLUSION

Field performance of the PTO driven disk tiller was empirically evaluated using a microcomputer-based data acquisition system. Based on the findings of this study the following statements can be made in conclusion:

1. Total power to the PTO driven disk tiller is split into two components; approximately 7 to 10 % was transferred to the implement through the drive wheels and 90 to 93 % through the PTO shaft.

2. Drawbar power requirement decreased with increasing ground speed due to loss in tillage depth. The reduction was up to 30 % at a peripheral disk velocity to ground speed (pdv/gs) ratio of 2.5. Total power requirement remained constant with increasing ground speed at constant disk peripheral velocity. Total power, however, increased in direct proportion to increases in disk peripheral velocity (PTO speed).

3. In answer to the question; was there any significant saving in power utilization by transferring engine power to the implement through the PTO shaft?, the following observations were made:

- 30 % reduction in total specific power (Kw/cm) was attainable at the low PTO speed (540 rpm) when compared to a free rolling disk tiller of the same size and mass. That was considered significant.

-there were no significant savings in power at higher PTO speeds (760 rpm and 1000 rpm) where the desirable quality might be attained. In fact total specific power requirements increased with increasing peripheral disk velocity.

4. The effect of PTO powering was most evident in wet soil conditions. The quality of work was much improved; the power driven disk tiller provided acceptable cutting ability, soil pulverization and mulch incorporation at a pdv/gs ratio range of 2.5 to 3 under these soil conditions.

5. The PTO driven disk tiller's performance was greatly handicapped in dry soil conditions. The cutting ability was significantly reduced in such conditions and mulch was not incorporated.

CHAPTER VIII

Recommendations for Future Work

1. Further field testing of the PTO driven disk tiller is needed in a wider range of soils and operating conditions typical of the Michigan agricultural year.

2. Tillage depth variation was found to significantly affect drawbar power requirement. Tillage depth therefore needs to be controlled and monitored by some form of instrumentation as integral part of the data acquisition system .

3. Side force should be monitored to determine its magnitude and its effect on tractor steerability, especially at higher ground speeds.

4. For consistency in the overall field evaluation; two tractors in tandem (as was done at 760 rpm) should be used. This will allow greater control of both the peripheral disk velocity (PTO speed) and ground speed and conclusively indentify the pdv/gs ratio of optimum energy utilization and desirable tillage condition.

5. There is need for qualitative evaluation (photographically) for all test runs which have numerical data.

6. Measure power disk impact on soil compaction compared with free rolling disk.

7. Following the high disk blade wear rate experienced in these tests, material composition analysis of the disk blades will provide a basis for proper selection of the blades required in powered applications such as this.

8. The PTO driven disk tiller's performance has been evaluated independently. To put its performance in perspective, comparative evaluation to other common use tillers should be carried out.

9. Systems studies are required to compare the total tillage system for the Power Disk with the system for other implements. The Power Disk may be able to replace primary tillage plus one or more secondary tillage operations.

APPENDICES

APPENDIX A

APPENDIX A

Appendix A outlines the Implement Performance Equations used and disk geometry in the subrutine ANALYZE.TEMBO (Appendix C). The data were analyzed statistically and printed in tabular form (Appendix D).

APPENDIX A. IMPLEMENT PERFORMANCE EQUATIONS.

(Calculations were Based on Mean Values)

SYMBOLS USED IN THE PERFORMANCE EQUATIONS

RRH	:	Rear Right Horizontal Force
RLH	:	Rear Left Horizontal Force
RRV	:	Rear Right Vertical Force
RLV	:	Rear Left Vertical Force
Fh	:	Component Horizontal Force
Fv	:	Component Vertical Force
Rr	:	Rear Wheel Peripheral Velocity
Rf	:	Front Wheel Peripheral Velocity (Ground Speed)
PI	:	3.14159654
N	:	Engine RPM
T	:	PTO Torque
PDV	:	Peripheral Disk Velocity
PDV/GS	:	Peripheral Disk Velocity to Ground Speed Ratio

1. PTO SHAFT ROTATION (RPM):

PTO RPM = (Measured engine RPM/Rated engine RPM)*STD PTO RPM

STD PTO RPM = 540, 1000 RPM

2. IMPLEMENT DRAFT REQUIREMENT(N):

DRAFT = NET HORIZONTAL FORCES

= RRH(I) + RLH(I)

3. DRIVE WHEEL SLIP (%) :

SLIP = (Rr - Rf)/Rr *100

4.DRAWBAR POWER (KW):

DRAWBAR (KW) = [RRH(I) + RLH(I)] * Rf

= (N * Km/h)/3600 (KW)

5.PTO POWER (KW):

PTO POWER (KW) = (2*PI*PTO RPM * T)/60 000 (KW)

= (2*PI*N*T)/60 000 (KW)

6.TOTAL POWER (KW):

TOTAL POWER = DRAWBAR POWER + PTO POWER

= [RRH(I)+RLH(I)]*Rf + (2*PI*N*T)/60 000 (KW)

7. THE DISK:

DISK ANGLE = 31

DISK BLADE DIA.(D) = 633 mm

RADIUS OF CURVITURE = 602 mm

DISK SPEED REDUCTION FROM THE SHAFT;

= GEAR REDUCTION RATIO*CHAIN DRIVE REDUCTION

= (10/33)*(10/14)

= 0.21645

PERIPHERAL DISK VELOCITY (PDV) (Km/h):

PDV (Km/h) = PTO RPM* 0.21645*(PI*D/rev)*60min/Hr*Km/1000m

PERIPHERAL DISK VELOCITY TO GROUND SPEED RATIO (PDV/GS):

PDV/GS RATIO = PDV/Rf

APPENDIX B

APPENDIX B

Appendix B shows the performance specifications of the transducers and some of the instrumentation used. A summary of the calibration procedures employed for each transducer is outlined. Table 6.2.1 lists the calibration response equations for the transducers used.

APPENDIX B: CALIBRATION DATA AND SPECIFICATIONS

Appendix B.1. Radar ground speed sensor

Sensor Origin:	Dickey john Corporation.
Velocity Range:	0 t0 80Km/h
Accuracy (Typical):	+/-1% at 35 degrees mounting angle
Recommended Mounting Angle:	Beam center to plane of earth should be 35 degrees +/-2 degrees.
Supply Voltage:	Unregulated battery voltage, 11 to 18 VDC
Supply Current:	300 mA
Output Signal:	Output frequency 100Hz/m/sec (44.7Hz/mph) Output voltage amplitude maximum low level 6 Volts, minimum high7 Volts.

Appendix B.2. Engine RPM sensor

Sensor Origin:	Dickey john Corporation
Specifications:	30 to 4000 Hz 3 V p-p 4 pulses per engine revolution

Calibration procedure:

1. Determine maximum rotational engine speed: 2100 rpm (35rps)
2. Determine frequency at maximum engine rps: 140 Hz (35*4)
3. Load a Frequency to Voltage Converter(F/V) with known frequency.

The accurracy of the engine speed measurement becomes a function of the accuracy of the frequency generator used (Wavetek, Model 182A, 4MHz frequency generator).

Response Calibration equation:

$$Hz = 1.3038 + 33.5904 * voltage$$

Output voltage: 0 to 5 Volts

The M1080 F/V converter had an R^2 value of 0.9998; error source would be in reading the frequency generator dial gauge (parallex error).

Appendix B. 3. Front and Rear Wheel Rotational Speed

Sensor Origin: Wabash Inc.

Type and Model: Magnetic pick up(cylinderical pole piece 60-0198"G", 2.5 inches reach

Specification: 14 V p-p at 30 inches/second, 0.050" air gap.

Calibration Procedure:

1. Establish desired resolution: 2 Km/h (First Gear-Low One)
2. Determine front and rear wheel rolling radii:
   - -front wheel rolling radius, Rf = 0.55 m
   - -rear wheel rolling radius, Rr = 0.70 m
3. Gear/Sprocket size:
   - -front wheel sprocket = 60 teeth
   - -rear wheel sprocket = 80 teeth
4. Determine wheel rotational circumference = 1 rev = PI*D

-front wheel circumference = 1.10 m /rev

-rear wheel circumference = 1.40 m /rev

Velocity, v = D*N

Wheel rotation speed, N = v/PI*D

Front wheel rotational speed, Nf = v/PI*Df

$$= \frac{2.0 * 1000/3600}{1.1*PI}$$

0.162 revs/sec

Frequency output = # of teeth * N/60

Frequency output signal for the front wheel:

=60 * 0.162 revs/sec

=9.72 Hz

Frequency output signal for the rear wheel:

=80 * 0.127

=10.18 Hz

4. Check if output signal is within detectable range of M1080 F/V converter on an oscilloscope by rotating wheel at the defined speed. Check effect of vibration on output signal .

5. Determine operational range: 0 to 10 Km/h (0 to 80 Hz)

6. Load F/V converter with known frequency, over defined range.

7. Response Calibration Equation:

Front wheel load (Hz) = -0.64516 + 25.334 * voltage

Rear wheel load (Hz) = - 0.59581 + 24.9019* voltage

Output signal range: front wheel signal 0 to 5 volts

rear wheel signal 0 to 5 volts

Accuracy: +/- 1.11%

Appendix B. 4. PTO Torquemeter

Sensor Origin: Mie University, Japan.

Specification: Slip ring on shaft instrumented with four arm, 120 Ohm full bridge assembly.

Calibration Procedure:

1. Determine calibration range from maximum tractor rated PTO power.

   For a 100 HP tractor with the standard 540rpm shaft:

PTO Power $= \frac{2*PI*N*T}{75*60}$

N is PTO rpm = 540

T is PTO Torque $= \frac{75 * 60 * 100}{2 *PI*540}$

Torque	= 132.6288 Kg-m
Torque in N-m	= 132.6288 * 9.80665
	= 1 300.644 N-m
Torque Range	= 0 to 1300 N-m

2. Subject the Torquemeter to step loading over the defined range.

3. Calibration response equation:

   Torque (N-m) = -17.088 + 789.73 * voltage

Excitation voltage:	2 Volts
Output range:	0 to 5 Volts
Accuracy:	+/- 2%

Appendix B. 5. Horizontal and Vertical Force Measurements

Sensor Origin:	Micromeasurements Inc.
Specifications:	Four arm 350 ohm full bridge assembly, bonded onto the three point hitch dynamometer.

Calibration Range (Static loading):

RRH:	0 to 4 500lbs
RLH:	0 to 4 500lbs
RRV:	0 to 2 500lbs
RLV:	0 to 2 500lbs

Top Link: 0 to 2 500lbs

Calibration Response Equation:

RRH = mV = -46.412 + 0.156 Fh + 179.5 - 0.47 Fv

RLH = mV = -27.496 - 0.066 Fh + 112.84 - 0.220 Fv

RRV = mV = 2.757 - 0.103 Fh + 30.374 - 1.113 Fv

RLV = mv = -4.068 - 0.021 Fh + 21.158 + 0.725 Fv

Top Link = lbs = 3.7104 + 3481 * voltage

Conversion of lbs to N multiply by [0.45350924 * 9.80665].

Excitation voltage: 10 Volts

Output voltage;

RRH: -1 to +1 Volts

RLH: -1 to +1 Volts

RRV: -5 to +5 Volts

RLV: -5 to +5 Volts

Top Link: -1 to +1 Volts

The accuracy of the force measurements is a function of;

-the accuracy of the M1060 signal conditioning amplifier

-the positioning of the strain gages about the X-Y axis

-the "directional purity" of the loading forces and

-the accuracy of the dynamometer (scale readability and frictional forces)

Accuracy: +/- 5%

Appendix B. 6. Strain Gage Amplifier

Origin:	Data Capture Technology Inc.
Specifications:	
Input configuration:	High Gain Differential
Input Impedence:	1 Megaohm Diffrential
Input Mode:	Resistive bridge in 1,2 or 4 arm connection with internal bridge completion
Input Range:	Up to 500mv
Maximum Input:	30v DC
CMR:	90dB (DC to 60Hz)
Noise:	Less than 5 microvolts r.m.s. (r.t.i.) at max gain
Drift:	Less than 2 microvolts/ C (r.t.i.) at max gain
Bandwidth:	DC - 10KHz
Gain:	20 - 5000 in switched steps with interpolate control.
Output (voltage):	Up to +/- 2 V DC
Output Impedence(voltage):	0.5 Ohms
Output (current):	+/-10mA into 120 Ohms
Output Impendence (current) :	250 Ohms

Appendix B. 7. AI13 Analog TO Digital Converter

Origin: Interactive Structures Inc.

Analog Specifications

Input Full Scale Ranges Available (millivolts):

0 to 5000	0 to 500	-5000 to +5000	-500 to +500
0 to 1000	0 to 100	-1000 to +1000	-100 t0 +100

Input Impedence: 10 MegaOhms

Crosstalk from unselected channel: -95dB

Conversion Specifications

Resolution : 12 Bits, 4096 steps

Coding: Binary, 0 to 4095 full scale.

Overrange Processing: Values greater than max. will appear as 4095.
Values less than min. will appear as 0.

Deviation from ideal step size: 0.024% max.

Deviation from the ideal straight line : 0.024% typical

Conversion Timing:

Selection and Sampling: 6 microseconds

Hold and Conversion: 13 microseconds

Total Conversion Time: 20 microseconds

Sampling Aperture: 125 nanoseconds

Settling time delays;

Channel switch, 5V or 1V scales:	none
Range switch, 5V or 1V scales:	none
Channel switch, .5V or .1V scales:	45 microseconds
Range switch, .5v or .1v scales :	45 microseconds

Electrical Requirements:

Internal Power:	Drawn from Apple Supply, 5V at 45mA, 12V at 19mA, -12V at 16mA
External Power:	None required.
External Trigger:	Positive or Negative Edge TTL.

APPENDIX C

APPENDIX C : DATA PROCESSING PROGRAM

AI13.MASTER is a general purpose data processing program. AI13.TEMBO was a modified version of AI13.MASTER with specific transducer characteristic inputs from the calibration subroutine. ANALYZE.TEMBO is a statistical subroutine in AI13.TEMBO and the results of its operation are shown in tabular form in Appendix D. Remarks are embedded in the program to allow the reader to follow through the whole operation with ease. Flow charts that explain the whole data acquisition process are detailed in Chapter Four.

```
100   REM PROGRAM AI13 MASTER
110   REM This program consists two parts : 1) calculate the results from data
120   REM file produced by APPLE IIe AI13.1 or AI13.2, 2) read file created by
130   REM part 1 of this program. The program is menu driven.
140   REM The data file should contain the following informations in sequence:
150   REM 1) Number of channels 2) Number of data per channel 3) channel
160   REM number and AI13 gain code in pair 4) digital data in block of
170   REM sampling set.
180   REM The result file contains the following informations : 1) number of
190   REM channels 2) number of data per channel 3) channel number 4) result.
200   REM ------------------------------------------------------------------
210   REM Because each transducer has its own characteristic, it is impossible
220   REM to write a general subroutine for all transducers. Thus each user
230   REM has to write his own subroutine for calculation. The area reserved
240   REM for this subroutine is from Line 10000 to Line 19999. The voltages
250   REM measured from transducers are stored in the array VOLT(I,J), where
260   REM I is the Ith channel in the group of channels, not the channel
270   REM number. J is the data point number. The result should be put into
280   REM array FORCE(I,J).
290   REM -----------------------------------------------------------------
300   REM However, if all of your transducers have the linear characteristics,
310   REM here is the subroutine that you can type in and use as it.
320   REM     10000 REM
330   REM     10010 REM -------------------------------------
340   REM     10020 REM
350   REM     10030 REM SUBROUTINE FOR LINEAR CALCULATION
360   REM     10040 FOR I=1 TO CHAN%
370   REM     10050 FOR J=1 TO SET%
380   REM     10060 RESU(I,J)=PARA(0,I)+PARA(1,I)*VOLT(I,J)
390   REM     10070 NEXT
400   REM     10080 NEXT
410   REM     10090 RETURN
420   REM where the parameters PARA(n,I) can be typed in each time you run the
430   REM program, or the program will provide you the option to save these
440   REM parameters for further use. Also, the program provides you the
450   REM option to edit them.
460   REM ------------------------------------------------------------------
470   REM The main variables in this program are :
480   REM     1) CHAN% - number of channels
490   REM     2) SET% - number of data set
500   REM     3) CODE%(1,CHAN%) - column 0 is channel number, column 1 is
510   REM        AI13 gain code.
520   REM     4) PARA(1,CHAN%) - array for transducers parameters, column
530   REM        0 is intersection, column 1 is slop.
540   REM     5) VOLT(CHAN%,SET%) - inicially for digit data, after cal-
550   REM        culation, it storers actual voltage.
560   REM     6) FORCE(CHAN%,SET%) - for storing results.
570   REM     7) INFILE$ - data file name
580   REM     8) PAFILE$ - parameters file name
590   REM     9) RSFILE$ - result file name
970   REM
980   REM -----------------------------------------------------------------
990   REM
1000   REM INITIALIZE PROGRAM
1010   HOME
1020   B$=CHR$(7)
1030   PRINT B$;"Please select an option :"
1040   PRINT"   1 - Get data file and parameters for calculation"
1050   PRINT"   2 - Get result file for verification"
1060   PRINT"   3 - Creating or editing parameter file only"
```

```
1070    PRINT"    4 - Quit the program"
1080    PRINT"Your option is :";:GET OPT
1090    IF OPT=1 THEN 2000
1100    IF OPT=2 THEN 4230
1110    IF OPT=3 THEN 7730
1120    IF OPT=4 THEN END
1130    PRINT OPT:PRINT"Please select option by its number":GOTO 1030
1970    REM
1980    REM ------------------------------------------------------------------
1990    REM
2000    REM MAIN ROUTINE TO GET DATA AND PARAMETERS
2010    ON ERR GOTO 2070
2020    HOME
2030    PRINT B$;"PUT DATA DISK IN DISK DRIVE"
2040    INPUT"GIVE ME THE DATA FILE NAME PRECEDED BY DRIVE # :";INFILE$
2050    UNLOCK INFILE$
2060    GOTO 2100:REM FILE EXISTS
2070    PRINT B$:INPUT"SORRY, I COULDN'T FIND THE FILE. DO YOU WANT TO TRY AGAI
        N?(Y/N)";ANSW$
2080    IF ANSW$="N" THEN END
2090    GOTO 2020
2100    OFF ERR
2110    OPEN#1 AS INPUT,INFILE$
2120    ON ERR GOTO 2230
2130    INPUT#1;CHAN%,SET%
2140    DIM CODE%(1,CHAN%),VOLT(CHAN%,SET%),FORCE(CHAN%,SET%),PARA(1,CHAN%),S(C
        HAN%)
2150    FOR I=1 TO CHAN%
2160      INPUT#1;CODE%(0,I),CODE%(1,I)
2170      NEXT
2180    FOR I=1 TO SET%:FOR J=1 TO CHAN%
2190        INPUT#1;VOLT(J,I)
2200        NEXT
2210      NEXT
2215    CLOSE#1
2220    GOTO 2290:REM SUCCESSFUL DATA INPUT
2230    IF ERR=4 THEN PRINT B$:PRINT"SORRY, YOUR DATA FILE HAS FEWER DATA THAN
        EXPECTED":GOTO 2250
2240    PRINT B$:PRINT"ERROR # "; ERR;" DETECTED IN YOUR DATA FILE
2250    CLOSE#1:STOP
2260    REM
2270    REM ------------------------------------------------------------------
2280    REM
2290    REM GET PARAMETERS
2300    HOME
2302    PRINT B$:INPUT"DO YOU NEED PARAMETERS ?(Y/N)";ANSW$
2304    IF ANSW$="N" THEN 2640
2306    IF ANSW$<>"Y" THEN 2302
2310    PRINT B$:INPUT"DO YOU HAVE TRANSDUCERS PARAMETER FILE ?(Y/N)";ANSW$
2320    IF ANSW$="Y" THEN 2450
2330    IF ANSW$<>"N" THEN 2310
2340    COUNT=0
2350    GOSUB 8690
2410    IF COUNT<CHAN% THEN 2350
2415    OPEN#1,".CONSOLE"
2420    GOSUB 8030:REM SHOW PARAMETERS
2430    GOSUB 8130:REM EDITING OR PRINTING PARAMETERS
2440    GOTO 2640:REM GO TO CALCULATION
2450    GOSUB 8800:REM GET PARAMETER FILE
2460    IF OPT=3 THEN 2340
2470    IF W%<>CHAN% THEN CLOSE#3:GOTO 9060
2480    ON ERR GOTO 2550
2490    COUNT=0
2500    FLAG=0
2510    READ#3;X,Y,Z
2520    FOR I=1 TO CHAN%
```

```
2530      IF X=CODE%(0,I) THEN PARA(0,I)=Y:PARA(1,I)=Z:FLAG=1:COUNT=COUNT+1:I=C
          HAN%
2540      NEXT
2550    IF FLAG=0 THEN OFF ERR:CLOSE#3:GOTO 9060
2560    IF COUNT<CHAN% THEN 2500
2570    OFF ERR:CLOSE#3
2580    OPEN#1,".CONSOLE"
2590    GOSUB 8030
2600    GOSUB 8130
2610    REM
2620    REM -------------------------------------------------------------
2630    REM
2640    REM BEGIN CALCULATIONS
2650    HOME
2655    PRINT"I AM CALCULATING RESULTS, IT WILL TAKE ABOUT 5 MINUTES."
2658    PRINT"YOU CAN GO FOR A COFFEE BREAK !!!"
2659    PRINT"BUT DON'T BRING COFFEE TO HERE, I DON'T LIKE IT !!!!!"
2660    FOR I=1 TO CHAN%
2670      ON CODE%(1,I)+1 GOSUB 11000,11100,11200,11300,11400,11500,11600,11700
2680      NEXT
2690    GOSUB 10000
2700    REM
2710    REM -------------------------------------------------------------
2720    REM
2730    REM OPTIONS FOR SAVING,CHECKING OR PRINTING RESULTS
2740    FLAG=0
2750    HOME
2760    PRINT B$;"PLEASE SELECT AN OPTION :"
2770    PRINT"   1 - SAVE THE RESULTS"
2780    PRINT"   2 - CHECK THE RESULTS"
2790    PRINT"   3 - PRINT THE RESULTS"
2800    PRINT"   4 - QUIT THE PROGRAM"
2810    PRINT"YOUR OPTION IS :";:GET OPT
2820    IF OPT=1 THEN 2900
2830    IF OPT=2 THEN 3270
2840    IF OPT=3 THEN 3730
2850    IF OPT=4 THEN 4530
2860    PRINT OPT:PRINT"PLEASE SELECT OPTION BY ITS NUMBER":GOTO 2760
2870    REM
2880    REM -------------------------------------------------------------
2890    REM
2900    REM SAVING RESULTS
2910    HOME
2912    IF FLAG=0 THEN 2920
2914    PRINT B$:INPUT"YOU HAVE ALREADY SAVED THE RESULT. DO YOU WANT TO SAVE A
        GAIN ?(Y/N)";ANSW$
2916    IF ANSW$="Y" THEN 2920
2918    GOTO 2750
2920    ON ERR GOTO 3010
2930    PRINT B$:PRINT"MAKE SURE YOU HAVE DISK WITH ENOUGH ROOM IN DISK DRIVE."
2940    INPUT"GIVE ME A FILE PATHNAME PRECEDED BY DISK DRIVE # :";REFILE$
2950    UNLOCK REFILE$
2960    PRINT B$:INPUT"FILE ALREADY EXISTS, OVERWRITE IT ANYWAY ?(Y/N)";ANSW$
2970    IF ANSW$="N" THEN 2940
2980    IF ANSW$<>"Y" THEN PRINT"PLEASE ANSWER Y OR N":GOTO 2960
2990    DELETE REFILE$
3000    GOTO 3030
3010    IF ERR=32 THEN PRINT"VOLUMN NOT FOUND":GOTO 2930
3020    IF ERR<>30 THEN PRINT"ERROR # "; ERR;" DETECTED. TRY AGAIN.":GOTO 2930
3030    OFF ERR
3040    ON ERR GOTO 3170
3050    OPEN#3 AS OUTPUT,REFILE$
3052    PRINT"I AM SAVING DATA, IT WILL TAKE ABOUT 4 MINUTES. DON'T DISTURB ME.
        "
3055    PRINT"YOU CAN GO TO FINISH YOUR COFFEE NOW."
3060    WRITE#3:CHAN%
```

```
3065    WRITE#3;SET%
3070    FOR I=1 TO CHAN%
3080      WRITE#3;CODE%(0,I)
3110      FOR J=1 TO SET%
3120        WRITE#3;FORCE(I,J)
3130        NEXT
3140      NEXT
3150    CLOSE#3:OFF ERR:HOME
3160    PRINT"SAVE SUCCESSFUL !!!":FLAG=1:GOTO 2760
3170    CLOSE#3:OFF ERR
3180    IF ERR=34 THEN PRINT"DISK FULL !":GOTO 2920
3190    PRINT"ERROR # "; ERR;" DETECTED."
3200    INPUT"DO YOU WANT TO TRY AGAIN ?(Y/N)";ANSW$
3210    IF ANSW$="Y" THEN 2920
3220    IF ANSW$="N"TEHN2750
3230    PRINT B$:PRINT"PLEASE ANSWER Y OR N":GOTO 3200
3240    REM
3250    REM -------------------------------------------------------------
3260    REM
3270    REM CHECK THE RESULTS
3280    HOME
3290    PRINT B$;"PLEASE SELECT ONE OPTION :"
3300    PRINT"   1 - CHECK PARTIAL RESULT OF ONE CHANNEL"
3310    PRINT"   2 - CHECK PARTIAL RESULT OF FIVE CHANNEL"
3320    PRINT"   3 - CHECK ALL RESULT OF ONE CHANNEL"
3330    PRINT"   4 - CHECK ALL RESULT OF FIVE CHANNEL"
3340    PRINT"   5 - QUIT CHECKING"
3350    PRINT"YOUR OPTION IS :";:GET OPT
3355    PRINT OPT
3360    IF OPT<1 OR OPT>5 THEN PRINT:PRINT"PLEASE SELECT OPTION BY ITS NUMBER":
        GOTO 3290
3370    IF OPT=5 THEN 2750
3375    IF(OPT=2 OR OPT=4) AND CHAN%<5 THEN PRINT"YOU HAVE LESS THAN 5 CHANNELS
        , PLEASE SELECT 1 OR 3":GOTO 3290
3380    IF OPT=3 OR OPT=4 THEN BEGIN=1:LAST=SET%:GOTO 3420
3390    PRINT:PRINT"GIVE ME THE BEGIN AND ENDING POINT (BETWEEN 1 AND ";SET%;")
        ,SEPARATED BY COMMA"
3400    INPUT BEGIN,LAST
3410    IF LAST<BEGIN THEN PRINT"ENDING POINT MUST BE GREATER THAN BEGIN POINT"
        :GOTO 3390
3420    IF OPT=2 OR OPT=4 THEN NUMB=5:GOTO 3440
3430    NUMB=1
3440    HOME
3460    COUNT=0
3470    CHECK=0
3480    INPUT"PLEASE GIVE ME ONE CHANNEL NUMBER YOU WANT :";X
3490    FOR I=1 TO CHAN%
3500      IF X=CODE%(0,I) THEN S(COUNT+1)=I:CHECK=1:I=CHAN%:COUNT=COUNT+1
3510      NEXT
3520    IF CHECK=0 THEN PRINT B$:PRINT"YOU GIVE ME WRONG CHANNEL NUMBER, TRY AG
        AIN":GOTO 3480
3530    IF COUNT<NUMB THEN 3470
3540    HOME
3550    IF NUMB=5 THEN 3620
3560    PRINT B$;"THE RESULT OF CHANNEL ";S(1);" ARE :"
3570    FOR I=BEGIN TO LAST
3580      PRINT FORCE(S(1),I),
3590      NEXT
3600    INPUT"PRESS RETURN TO CONTINUE";ANSW$
3610    GOTO 3280
3620    PRINT USING 3630;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(5)
3630    IMAGE 5X,4A,2#,5X
3640    FOR I=BEGIN TO LAST
3650      PRINT USING 3670;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(4)
          ,I),FORCE(S(5),I)
3660      NEXT
```

```
3670    IMAGE 3X,6#.3#,3X
3680    INPUT"PRESS RETURN TO CONTINUE";ANSW$
3690    GOTO 3280
3700    REM
3710    REM -----------------------------------------------------------------
3720    REM
3730    REM PRINTING RESULTS
3740    HOME
3750    PRINT B$;"PLEASE SELECT ONE OPTION :"
3760    PRINT"   1 - PRINT PARTIAL RESULT OF SOME CHANNEL"
3770    PRINT"   2 - PRINT PARTIAL RESULT OF ALL CHANNELS"
3780    PRINT"   3 - PRINT ALL RESULT OF SOME CHANNEL"
3790    PRINT"   4 - PRINT ALL RESULT OF ALL CHANNELS"
3800    PRINT"   5 - QUIT PRINTING"
3810    PRINT"YOUR OPTION IS :";:GET OPT
3820    PRINT OPT
3830    IF OPT<1 OR OPT>5 THEN PRINT:PRINT"PLEASE SELECT OPTION BY ITS NUMBER":
        GOTO 3750
3840    IF OPT=5 THEN 2750
3850    IF OPT=3 OR OPT=4 THEN BEGIN=1:LAST=SET%:GOTO 3890
3860    PRINT:PRINT"GIVE ME THE BEGIN AND ENDING POINT (BETWEEN 1 AND ";SET%;")
        , SEPARATED BY COMMA"
3870    INPUT BEGIN,LAST
3880    IF LAST<BEGIN THEN PRINT"ENDING POINT MUST BE GREATER THAN BEGIN POINT"
        :GOTO 3860
3890    IF OPT=2 OR OPT=4 THEN NUMB=CHAN%:GOTO 4020
3900    HOME
3910    INPUT"HOW MANY CHANNEL DO YOU WANT TO PRINT ?";NUMB
3920    IF NUMB>CHAN% THEN PRINT B$:PRINT"YOU HAVE ONLY ";CHAN%;" CHANNELS":GOT
        O 3910
3930    COUNT=0
3940    CHECK=0
3950    INPUT"PLEASE GIVE ME ONE CHANNEL NUMBER YOU WANT :";X
3960    FOR I=1 TO CHAN%
3970      IF X=CODE%(0,I) THEN S(COUNT+1)=I:CHECK=1:I=CHAN%:COUNT=COUNT+1
3980      NEXT
3990    IF CHECK=0 THEN PRINT B$:PRINT"YOU GIVE ME WRONG CHANNEL NUMBER, TRY AG
        AIN":GOTO 3950
4000    IF COUNT<NUMB THEN 3940
4010    GOTO 4050
4020    FOR I=1 TO CHAN%
4030      S(I)=I
4040      NEXT
4050    PRINT B$:PRINT"PLEASE GIVE ME THE HEADER FOR THIS PRINT OUT (MAX 80 CHA
        RACTERS)"
4060    INPUT HEADER$
4070    OPEN#4,".PRINTER"
4080    PRINT#4;CHR$(27)+CHR$(88)+CHR$(27)+CHR$(33)
4090    PRINT#4;HEADER$
4100    PRINT#4;CHR$(27)+CHR$(34)+CHR$(27)+CHR$(66)
4110    PRINT#4
4115    NO$=CHR$(27)+CHR$(89)
4120    IF NUMB<9 OR NUMB=16 THEN PRINT#4;CHR$(27)+CHR$(69):GOTO 4150
4130    IF NUMB<11 THEN PRINT#4;CHR$(27)+CHR$(113):GOTO 4150
4140    PRINT#4;CHR$(27)+CHR$(81)
4150    ON NUMB GOSUB 5000,5100,5200,5300,5400,5500,5600,5700,5800,5900,6000,61
        00,6200,6300,6400,6500
4160    PRINT#4;CHR$(12)+CHR$(27)+CHR$(99)
4170    CLOSE#4
4180    GOTO 3740
4200    REM
4210    REM -----------------------------------------------------------------
4220    REM
4230    REM PROGRAM FOR GETTING RESULT FILE
4240    ON ERR GOTO 4300
4250    HOME
```

```
4260    PRINT B$;"PUT RESULT DISK IN DRIVE"
4270    INPUT"GIVE ME THE RESULT FILE PATHNAME PRECEDED BY DRIVE # :";REFILE$
4280    LOCK REFILE$
4290    GOTO 4330
4300    PRINT B$:INPUT"SORRY, I COULDN'T FIND THE FILE. DO YOU WANT TO TRY AGAI
        N ?(Y/N)";ANSW$
4310    IF ANSW$="N" THEN END
4320    GOTO 4250
4330    OFF ERR
4340    OPEN#5 AS INPUT,REFILE$
4350    READ#5;CHAN%,SET%
4360    DIM CODE%(1,CHAN%),FORCE(CHAN%,SET%),S(CHAN%)
4370    FOR I=1 TO CHAN%
4380      READ#5;CODE%(0,I)
4390      FOR J=1 TO SET%
4400        READ#5;FORCE(I,J)
4410        NEXT
4420      NEXT
4430    CLOSE#5
4440    FLAG=1
4450    GOTO 2750
4500    REM
4510    REM ---------------------------------------------------------------
4520    REM
4530    REM ENDING THE PROGRAM
4540    IF FLAG=1 THEN 4600
4550    HOME
4560    PRINT B$:INPUT"YOU DIDN'T SAVE THE RESULTS, QUIT ANYWAY ?(Y/N)";ANSW$
4570    IF ANSW$="Y" THEN 4600
4580    IF ANSW$="N" THEN 2900
4590    PRINT:PRINT"PLEASE ANSWER Y OR N":GOTO 4560
4600    END
4960    REM
4970    REM ---------------------------------------------------------------
4980    REM
4990    REM SUBROUTINE FOR PRINTING RESULTS OF ONE CHANNEL
5000    PRINT#4;"RESULT OF CHANNEL ";CODE%(0,S(1))
5010    PRINT#4;NO$
5020    FOR I=BEGIN TO LAST
5030      PRINT#4;FORCE(S(1),I),
5040      NEXT
5050    RETURN
5080    REM
5090    REM SUBROUTINE FOR PRINTING RESULTS OF TWO CHANNELS
5100    PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2)
5110    PRINT#4;NO$
5120    FOR I=BEGIN TO LAST
5130      PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I)
5140      NEXT
5150    RETURN
5160    IMAGE 3X,4A,2#,3X
5170    IMAGE 1X,6#.2#,2X
5180    REM
5190    REM SUBROUTINE FOR PRINTING RESULTS OF THREE CHANNELS
5200    PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3)
5210    PRINT#4;NO$
5220    FOR I=BEGIN TO LAST
5230      PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I)
5240      NEXT
5250    RETURN
5280    REM
5290    REM SUBROUTINE FOR PRINTING RESULTS OF FOUR CHANNELS
5300    PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4)
5310    PRINT#4;NO$
5320    FOR I=BEGIN TO LAST
5330      PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
```

```
      4),I)
5340    NEXT
5350  RETURN
5380  REM
5390  REM SUBROUTINE FOR PRINTING RESULTS OF FIVE CHANNELS
5400  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5)
5410  PRINT#4;NO$
5420  FOR I=BEGIN TO LAST
5430    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I)
5440    NEXT
5450  RETURN
5480  REM
5490  REM SUBROUTINE FOR PRINTING RESULTS OF SIX CHANNELS
5500  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5),"CH.",S(6)
5510  PRINT#4;NO$
5520  FOR I=BEGIN TO LAST
5530    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I),FORCE(S(6),I)
5540    NEXT
5550  RETURN
5580  REM
5590  REM SUBROUTINE FOR PRINTING RESULTS OF SEVEN CHANNELS
5600  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5),"CH.",S(6),"CH.",S(7)
5610  PRINT#4;NO$
5620  FOR I=BEGIN TO LAST
5630    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I)
5640    NEXT
5650  RETURN
5680  REM
5690  REM SUBROUTINE FOR PRINTING RESULTS OF EIGHT CHANNELS
5700  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5),"CH.",S(6),"CH.",S(7),"CH.",S(8)
5710  PRINT#4;NO$
5720  FOR I=BEGIN TO LAST
5730    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I)
5740    NEXT
5750  RETURN
5780  REM
5790  REM SUBROUTINE FOR PRINTING RESULTS OF NINE CHANNELS
5800  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9)
5810  PRINT#4;NO$
5820  FOR I=BEGIN TO LAST
5830    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
        (9),I)
5840    NEXT
5850  RETURN
5880  REM
5890  REM SUBROUTINE FOR PRINTING RESULTS OF TEN CHANNELS
5900  PRINT#4 USING 5160;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
      5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10)
5910  PRINT#4;NO$
5920  FOR I=BEGIN TO LAST
5930    PRINT#4 USING 5170;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
        4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
        (9),I),FORCE(S(10),I)
5940    NEXT
5950  RETURN
5980  REM
```

```
5990    REM SUBROUTINE FOR PRINTING RESULTS OF ELEVEN CHANNELS
6000    PRINT#4 USING 6060;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
        5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10),"CH.",S(11)
6010    PRINT#4;NO$
6020    FOR I=BEGIN TO LAST
6030      PRINT#4 USING 6070;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
          4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
          (9),I),FORCE(S(10),I),FORCE(S(11),I)
6040      NEXT
6050    RETURN
6060    IMAGE 1X,4A,2#,2X
6070    IMAGE 5#.2#,1X
6080    REM
6090    REM SUBROUTINE FOR PRINTING RESULTS OF TWELVE CHANNELS
6100    PRINT#4 USING 6060;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
        5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10),"CH.",S(11),
        "CH.",S(12)
6110    PRINT#4;NO$
6120    FOR I=BEGIN TO LAST
6130      PRINT#4 USING 6070;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
          4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
          (9),I),FORCE(S(10),I),FORCE(S(11),I),FORCE(S(12),I)
6140      NEXT
6150    RETURN
6180    REM
6190    REM SUBROUTINE FOR PRINTING RESULTS OF THIRTEEN CHANNELS
6200    PRINT#4 USING 6060;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
        5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10),"CH.",S(11),
        "CH.",S(12),"CH.",S(13)
6210    PRINT#4;NO$
6220    FOR I=BEGIN TO LAST
6230      PRINT#4 USING 6070;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
          4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
          (9),I),FORCE(S(10),I),FORCE(S(11),I),FORCE(S(12),I),FORCE(S(13),I)
6240      NEXT
6250    RETURN
6280    REM
6290    REM SUBROUTINE FOR PRINTING RESULTS OF FOURTEEN CHANNELS
6300    PRINT#4 USING 6060;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
        5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10),"CH.",S(11),
        "CH.",S(12),"CH.",S(13),"CH.",S(14)
6310    PRINT#4;NO$
6320    FOR I=BEGIN TO LAST
6330      PRINT#4 USING 6070;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
          4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
          (9),I),FORCE(S(10),I),FORCE(S(11),I),FORCE(S(12),I),FORCE(S(13),I),FO
          RCE(S(14),I)
6340      NEXT
6350    RETURN
6380    REM
6390    REM SUBROUTINE FOR PRINTING RESULTS OF FIFTEEN CHANNELS
6400    PRINT#4 USING 6060;"CH.",S(1),"CH.",S(2),"CH.",S(3),"CH.",S(4),"CH.",S(
        5),"CH.",S(6),"CH.",S(7),"CH.",S(8),"CH.",S(9),"CH.",S(10),"CH.",S(11),
        "CH.",S(12),"CH.",S(13),"CH.",S(14),"CH.",S(15)
6410    PRINT#4;NO$
6420    FOR I=BEGIN TO LAST
6430      PRINT#4 USING 6070;FORCE(S(1),I),FORCE(S(2),I),FORCE(S(3),I),FORCE(S(
          4),I),FORCE(S(5),I),FORCE(S(6),I),FORCE(S(7),I),FORCE(S(8),I),FORCE(S
          (9),I),FORCE(S(10),I),FORCE(S(11),I),FORCE(S(12),I),FORCE(S(13),I),FO
          RCE(S(14),I),FORCE(S(15),I)
6440      NEXT
6450    RETURN
6480    REM
6490    REM SUBROUTINE FOR PRINTING RESULTS OF SIXTEEN CHANNELS
6500    GOSUB 5700
6510    PRINT#4;CHR$(12)+CHR$(27)+CHR$(88)
```

```
6520    FOR I=1 TO 8
6530      S(I)=S(I+8)
6540      NEXT
6550    GOSUB 5700
6560    RETURN
7700    REM
7710    REM -------------------------------------------------------------
7720    REM
7730    REM ROUTINE FOR CREATING OR EDITING PARAMETERS ONLY
7740    HOME
7750    PRINT B$:INPUT"DO YOU HAVE PARAMETER FILE ?(Y/N)";ANSW$
7760    IF ANSW$="Y" THEN 7870
7770    IF ANSW$<>"N" THEN 7850
7780    INPUT"HOW MANY CHANNELS DO YOU HAVE ?";CHAN%
7790    DIM CODE%(1,CHAN%),PARA(1,CHAN%)
7800    FOR I=1 TO CHAN%
7810      INPUT"GIVE ME THE CHANNEL NUMBER, INTERSECTION AND SLOP, SEPARATED BY
           COMMA :";CODE%(0,I),PARA(0,I),PARA(1,I)
7820      NEXT
7830    OPEN#1,".CONSOLE"
7840    GOSUB 8030
7850    GOSUB 8130
7860    END
7870    GOSUB 8800
7875    IF OPT=3 THEN 7780
7880    CHAN%=W%
7890    DIM CODE%(1,CHAN%),PARA(1,CHAN%)
7900    FOR I=1 TO CHAN%
7910      READ#3;CODE%(0,I),PARA(0,I),PARA(1,I)
7920      NEXT
7930    CLOSE#3
7940    OPEN#1,".CONSOLE"
7950    GOSUB 8030
7960    GOSUB 8130
7970    END
8000    REM
8010    REM -------------------------------------------------------------
8020    REM
8030    REM SUBROUTINE TO SHOW PARAMETERS
8040    HOME:PRINT#1;"THE CHANNEL NUMBER, INTERSECTION AND SLOP ARE :"
8050    PRINT#1:PRINT#1;"CHANNEL","INTERSECTION","SLOP"
8060    FOR I=1 TO CHAN%
8070      PRINT#1;CODE%(0,I),PARA(0,I),PARA(1,I)
8080      NEXT
8085    CLOSE#1
8090    PRINT:PRINT"PRESS RETURN TO CONTINUE"
8100    GET ANSW$
8110    RETURN
8115    REM
8120    REM -------------------------------------------------------------
8125    REM
8130    REM SUBROUTINE FOR EDITING PARAMETERS
8140    HOME
8150    PRINT:PRINT"PLEASE SELECT ONE OPTION :"
8160    PRINT"   1 - EDITING PARAMETERS"
8170    PRINT"   2 - SAVING PARAMETERS"
8180    PRINT"   3 - PRINTING PARAMETERS"
8190    PRINT"   4 - QUIT PARAMETER SECTION"
8200    PRINT"YOUR OPTION IS :";:GET OPT
8210    IF OPT=4 THEN RETURN
8220    IF OPT=3 THEN 8610
8230    IF OPT=2 THEN 8320
8240    IF OPT<>1 THEN PRINT B$:PRINT"PLEASE SELECT OPTION BY ITS NUMBER":GOTO
        8150
8250    COUNT=CHAN%-1
8260    GOSUB 8690:REM GO TO EDIT PARAMETERS
```

```
8265   OPEN#1,".CONSOLE"
8270   GOSUB 8030
8280   GOTO 8140
8290   REM
8300   REM ----------------------------------------------------------------
8310   REM
8320   REM SUBROUTINE FOR SAVING PARAMETERS
8330   ON ERR GOTO 8420
8340   HOME
8350   PRINT B$:INPUT"GIVE ME THE FILE PATHNAME PRECEDED BY DISK DRIVE # :";PA
       FILE$
8360   UNLOCK PAFILE$
8370   PRINT B$:INPUT"FILE ALREADY EXISTS, OVERWRITE IT ANYWAY ?(Y/N)";ANSW$
8380   IF ANSW$="N" THEN 8350
8390   IF ANSW$<>"Y" THEN 8370
8400   DELETE OAFILE$
8410   GOTO 8480
8420   IF ERR=32 THEN PRINT:PRINT"VOLUMN NOT FOUND":GOTO 8350
8430   IF ERR=30 THEN 8480
8440   PRINT:PRINT"ERROR # "; ERR;" DETECTED."
8450   INPUT"DO YOU WANT TO TRY AGAIN ?(Y/N)";ANSW$
8460   IF ANSW$="N"TEHN8560
8470   GOTO 8350
8480   OPEN#2 AS OUTPUT,PAFILE$
8490   WRITE#2;CHAN%
8500   FOR I=1 TO CHAN%
8510     WRITE#2;CODE%(0,I)
8520     WRITE#2;PARA(0,I)
8530     WRITE#2;PARA(1,I)
8540     NEXT
8550   CLOSE#2
8560   OFF ERR
8570   GOTO 8140
8580   REM
8590   REM -------------------------------------------------------------
8600   REM
8610   REM SUBROUTINE FOR PRINTING PARAMETERS
8620   OPEN#1,".PRINTER"
8630   PRINT B$:INPUT"TURN ON PRINTER, THEN PRESS RETURN";ANSW$
8640   GOSUB 8030
8650   GOTO 8140
8660   REM
8670   REM -------------------------------------------------------------
8680   REM
8690   REM SUBROUTINE FOR EDITING PARAMETERS
8700   FLAG=0
8710   PRINT B$:INPUT"GIVE ME THE CHANNEL NUMBER, INTERSECTION AND SLOP, SEPAR
       ATED BY COMMA :";X,Y,Z
8720   FOR I=1 TO CHAN%
8730     IF X=CODE%(0,I) THEN PARA(0,I)=Y:PARA(1,I)=Z:FLAG=1:COUNT=COUNT+1:I=C
         HAN%
8740     NEXT
8750   IF FLAG=0 THEN PRINT:PRINT"YOU GIVE ME WRONG CHANNEL NUMBER, TRY AGAIN.
       ":GOTO 8710
8760   RETURN
8770   REM
8780   REM -------------------------------------------------------------
8790   REM
8800   REM SUBROUTINE TO GET PARAMETER FILE
8810   HOME
8820   ON ERR GOTO 8880
8830   PRINT B$:INPUT"GIVE ME THE PARAMETER FILE PATHNAME PRECEDED BY DRIVE #
       :";PAFILE$
8840   UNLOCK PAFILE$
8850   OPEN#3,PAFILE$
8860   READ#3;W%
```

```
8870   OFF ERR:RETURN
8880   PRINT B$:PRINT"ERROR # "; ERR;" DETECTED. PLEASE SELECT OPTION :"
8890   PRINT"   1 - TRY AGAIN"
8900   PRINT"   2 - CATALOG TO CHECK FILE NAME"
8910   PRINT"   3 - GO TO CREATE NEW PARAMETER FILE"
8920   PRINT"   4 - QUIT THE PROGRAM"
8930   PRINT"YOUR OPTION IS :";:GET OPT:PRINT OPT
8940   IF OPT=4 THEN STOP
8950   IF OPT=3 THEN 8870
8960   IF OPT=1 THEN 8830
8965   ON ERR GOTO 9022
8970   INPUT"PLEASE TYPE .D1 OR .D2 FOR CATALOG :";ANSW$
8980   CATALOG ANSW$
8985   OFF ERR
8990   INPUT"CATALOG AGAIN ?(Y/N)";ANSW$
9000   IF ANSW$="Y" THEN 8970
9010   IF ANSW$="N" THEN 8820
9020   GOTO 8990
9022   PRINT B$:PRINT"VOLUMN NOT FOUND. PLEASE PUT DISK INTO DRIVE.":OFF ERR:G
       OTO 8970
9030   REM
9040   REM ----------------------------------------------------------------
9050   REM
9060   REM RESCUE THE PARAMETER FILE ERROR
9070   PRINT B$:PRINT"SORRY, YOUR PARAMETER FILE DOESN'T MATCH DATA FILE. WHAT
        DO YOU WANT ?"
9080   PRINT"   1 - TRY ANOTHER PARAMETER FILE"
9090   PRINT"   2 - CREATE NEW PARAMETER FILE"
9100   PRINT"   3 - QUIT PROGRAM"
9110   PRINT"YOUR OPTION IS :";:GET OPT:PRINT OPT
9120   IF OPT=3 THEN STOP
9130   IF OPT=2 THEN 2340
9140   IF OPT=1 THEN 2450
9150   PRINT:PRINT"PLEASE SELECT OPTION BY ITS NUMBER":GOTO 9070
9970   REM
9980   REM ----------------------------------------------------------------
9990   REM
10000   REM SUBROUTINE FOR CALCULATION
10010   DIM A(10),M(10),B(4),N(4)
10015   SI=4.448222
10020   A(1)=-46.412
10030   M(1)=0.156
10040   B(1)=179.5
10050   N(1)=-0.437
10060   A(2)=-27.496
10070   M(2)=0.066
10080   B(2)=12.841
10090   N(2)=-0.220
10100   A(3)=30.374
10110   M(3)=1.113
10120   B(3)=2.757
10130   N(3)=-0.103
10140   A(4)=21.158
10150   M(4)=0.725
10160   B(4)=-4.068
10170   N(4)=-0.021
10180   A(5)=11.82
10190   M(5)=3455
10200   A(6)=19.56
10210   M(6)=503.85
10220   A(7)=0.03989
10230   M(7)=3.575
10240   A(8)=-0.1348
10250   M(8)=5.632
10260   A(9)=-0.13377
10270   M(9)=5.2529
```

```
10280   A(10)=17.088
10290   M(10)=789.73
10300   DET1=M(1)*M(3)-N(1)*N(3)
10310   DET2=M(2)*M(4)-N(2)*N(4)
10320   TAIL1=A(3)*N(1)+B(3)*N(1)-A(1)*M(3)-B(1)*M(3)
10330   TAIL2=A(4)*N(2)+B(4)*N(2)-A(2)*M(4)-B(2)*M(4)
10340   TAIL3=A(1)*N(3)+B(1)*N(3)-A(3)*M(1)-B(3)*M(1)
10350   TAIL4=A(2)*N(4)+B(2)*N(4)-A(4)*M(2)-B(4)*M(2)
10360   FOR I=1 TO SET%
10370     FORCE(1,I)=(1000*M(3)*VOLT(1,I)-1000*N(1)*VOLT(3,I)+TAIL1)/DET1*SI
10380     FORCE(3,I)=(1000*M(1)*VOLT(3,I)-1000*N(3)*VOLT(1,I)+TAIL3)/DET1*SI
10390     FORCE(2,I)=(1000*M(4)*VOLT(2,I)-1000*N(2)*VOLT(4,I)+TAIL2)/DET2*SI
10400     FORCE(4,I)=(1000*M(2)*VOLT(4,I)-1000*N(4)*VOLT(2,I)+TAIL4)/DET2*SI
10405     FORCE(5,I)=(A(5)+M(5)*VOLT(5,I))*SI
10410     FOR J=6 TO 10
10420       FORCE(J,I)=A(J)+M(J)*VOLT(J,I)
10430       NEXT
10440     NEXT
10450   RETURN
10960   REM
10970   REM -----------------------------------------------------------
10980   REM
10990   REM SUBROUTINE FOR CONVERTING VOLTAGE CODE TO REAL VOLTAGE
11000   FOR J=1 TO SET%
11010     VOLT(I,J)=VOLT(I,J)*5/4096
11020     NEXT
11030   RETURN
11100   FOR J=1 TO SET%
11110     VOLT(I,J)=VOLT(I,J)/4096
11120     NEXT
11130   RETURN
11200   FOR J=1 TO SET%
11210     VOLT(I,J)=VOLT(I,J)*5/40960
11220     NEXT
11230   RETURN
11300   FOR J=1 TO SET%
11310     VOLT(I,J)=VOLT(I,J)/40960
11320     NEXT
11330   RETURN
11400   FOR J=1 TO SET%
11410     VOLT(I,J)=(VOLT(I,J)-2048)*5/2048
11420     NEXT
11430   RETURN
11500   FOR J=1 TO SET%
11510     VOLT(I,J)=(VOLT(I,J)-2048)/2048
11520     NEXT
11530   RETURN
11600   FOR J=1 TO SET%
11610     VOLT(I,J)=(VOLT(I,J)-2048)*5/20480
11620     NEXT
11630   RETURN
11700   FOR J=1 TO SET%
11710     VOLT(I,J)=(VOLT(I,J)-2048)/20480
11720     NEXT
11730   RETURN
```

```
100   REM PROGRAM ANALYZER
110   HOME:B$=CHR$(7)
120   ON ERR GOTO 200
130   PRINT B$;"PLEASE GIVE ME THE DATA FILE PATHNAME PRECEDED BY DISK DRIVE #
       :"
140   INPUT REFILE$
150   PRINT B$:INPUT"WHAT IS THE PTO RPM ?";RPM
160   IF RPM<600 THEN PTO=27/95:GOTO 180
170   PTO=1/2.06
180   LOCK REFILE$
190   OFF ERR:GOTO 210
200   PRINT B$;"ERROR # "; ERR;" DETECTED":END
210   OPEN#1 AS INPUT,REFILE$
220   READ#1;CHAN%,SET%
230   DIM CODE(CHAN%),FORCE(18,SET%),MAX(18),MIN(18),AVERAGE(18),TITL$(18),DEV
      (18),CV(18)
240   FOR I=1 TO CHAN%
250     READ#1;CODE(I)
260     FOR J=1 TO SET%
270       READ#1;FORCE(I,J)
280       NEXT
290     NEXT
300   CLOSE#1
310   HR=3600
320   DISK=3.14159*0.633*PTO*6/462
330   RAT=2*3.14159*PTO/60000
335   CEM=100
340   TITL$(1)="RIGHT DRAFT (N)"
350   TITL$(2)="LEFT DRAFT (N)"
360   TITL$(3)="RIGHT LIFT (N)"
370   TITL$(4)="LEFT LIFT (N)"
380   TITL$(5)="TOP TENSION (N)"
390   TITL$(6)="ENGINE RPM"
395   TITL$(7)="PTO RPM"
400   TITL$(8)="WHEEL SPEED (Km/h)"
410   TITL$(9)="GROUND SPEED (Km/h)"
420   TITL$(10)="TORQUE (N-M)"
430   TITL$(11)="NET DRAFT (N)"
440   TITL$(12)="NET LIFT (N)"
450   TITL$(13)="SLIPPAGE (%)"
460   TITL$(14)="DRAW POWER (Kw)"
470   TITL$(15)="PTO POWER (Kw)"
480   TITL$(16)="TOTAL POWER (Kw)"
485   TITL$(17)="DISK SPEED (Km/h)"
487   TITL$(18)="PDV/GS RATIO"
490   HOME:PRINT B$;"I AM CALCULATING NET FORCES AND POWERS"
500   FOR I=1 TO SET%
510     FORCE(10,I)=0:REM PTO IS DISENGAGED
520     FORCE(11,I)=FORCE(1,I)+FORCE(2,I):REM NET PULL
530     FORCE(12,I)=FORCE(3,I)+FORCE(4,I):REM NET VERTICAL
540     FORCE(13,I)=(FORCE(8,I)-FORCE(9,I))*CEM/FORCE(8,I):REM SLIPPAGE
550     FORCE(14,I)=FORCE(11,I)*FORCE(9,I)/HR:REM PULL KW
555     FORCE(7,I)=FORCE(6,I)*PTO:REM PTO RPM
560     FORCE(15,I)=FORCE(10,I)*FORCE(6,I)*RAT:REM PTO KW
570     FORCE(16,I)=FORCE(14,I)+FORCE(15,I):REM NET KW
580     FORCE(17,I)=DISK*FORCE(6,I):REM DISK SPEED
585     FORCE(18,I)=FORCE(17,I)/FORCE(9,I):REM PDV/GS RATIO
590     NEXT
790   FOR I=1 TO 18
800     PRINT"I AM SORTING CHANNEL ";I
810     SUM=0
815     SS=0
```

```
820      MAX(I)=-99999
830      MIN(I)=99999
840      FOR J=1 TO SET%
850        IF FORCE(I,J)>MAX(I) THEN MAX(I)=FORCE(I,J)
860        IF FORCE(I,J)<MIN(I) THEN MIN(I)=FORCE(I,J)
870        SUM=SUM+FORCE(I,J)
875        SS=SS+FORCE(I,J)^2
880        NEXT
890      AVERAGE(I)=SUM/SET%
892      DEV(I)=SQR((SS-SUM*SUM/SET%)/(SET%-1))
894      CV(I)=100*DEV(I)/AVERAGE(I)
900      NEXT
1000    HOME
1010    PRINT B$;"PLEASE GIVE ME A FILE PATHNAME FOR OUTPUT :"
1020    INPUT OUT$
1030    PRINT B$:PRINT"TURN ON THE PRINTER. GIVE ME A HEADER FOR THIS PRINT OUT
         :"
1040    INPUT HEAD$
1050    OPEN#2,".PRINTER"
1060    OPEN#3,OUT$
1070    PRINT#2;HEAD$:PRINT#2
1080    PRINT#2 USING 1160;"MAXIMUM","MINIMUM","AVERAGE","STD. DEV.","COEF. VAR
        ."
1090    FOR I=1 TO 18
1110      PRINT#2 USING 1170;TITL$(I),MAX(I),MIN(I),AVERAGE(I),DEV(I),CV(I)
1120      WRITE#3;MAX(I),MIN(I),AVERAGE(I),DEV(I),CV(I)
1150      NEXT
1160    IMAGE 22X,12C,12C,12C,12C,12C
1170    IMAGE 20A,9#.2#,9#.2#,9#.2#,9#.2#,9#.2#
1180    PRINT#2;CHR$(10),CHR$(10),CHR$(10)
1190    CLOSE#2
1200    CLOSE#3
1210    END
```

APPENDIX D

APPENDIX D : STATISTICAL ANALYSIS RESULTS

Subroutine ANALYZE.TEMBO was a specific statistical program in the processing program AI13.TEMBO (Appendix C) which summarized the 700 data points recorded per variable into:

Maximum values

Minimum values

Average values

Standard deviation and

Coefficient of Variation (% basis).

All calculations were based on average values. Maximum and minimum values occured at different times, therefore calculations and/or comparisons based on the maximum and minimum values would be incorrect. For example in the first table (Test Run 1), Net Draft (12 547.1 N) is the sum of theaverage Right Draft and Left Draft (2 541.66 N + 10 005.4 N). Calculations of all derived variables are outlined in Appendix A.

The head line at each table lists: the test number, drive gear selected, test site, average soil moisture content of field tested, average tillage depth and date of field testing, in that order.

T3.L03.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =19.05CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	14155.90	-5132.73	710.92	3319.99	467.00
LEFT DRAFT (N)	14099.80	-14367.60	4844.40	3008.40	62.10
RIGHT LIFT (N)	4608.66	-240.26	1765.79	873.01	49.44
LEFT LIFT (N)	33.93	-6711.13	-1817.40	694.44	-38.21
TOP TENSION (N)	-247.59	-8081.98	-1796.21	800.75	-44.58
ENGINE RPM	1991.41	1934.83	1964.59	10.81	0.55
PTO RPM	565.98	549.90	558.36	2.96	0.53
WHEEL SPEED (Km/h)	4.54	4.27	4.41	0.05	1.24
GROUND SPEED (Km/h)	4.16	3.55	3.89	0.12	3.02
TORQUE (N-M)	518.91	254.77	391.21	42.19	10.78
NET DRAFT (N)	20748.00	-14594.60	5555.32	4706.31	84.72
NET LIFT (N)	2164.04	-2325.86	-51.60	661.56	-1281.99
SLIPPAGE (%)	19.51	4.84	11.72	2.62	22.39
DRAW POWER (Kw)	21.64	-15.26	5.95	5.01	84.16
PTO POWER (Kw)	30.41	14.80	22.87	2.44	10.68
TOTAL POWER (Kw)	45.11	0.83	28.82	5.43	18.83
DISK SPEED (Km/h)	14.62	14.20	14.42	0.08	0.55
PDV/GS RATIO	4.00	3.46	3.71	0.10	2.75

T4.L03.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =19.05CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	17593.60	-6384.79	2380.45	3544.53	148.90
LEFT DRAFT (N)	22004.20	-5060.19	6579.44	3714.72	56.46
RIGHT LIFT (N)	5393.07	-3843.08	2086.62	867.41	41.57
LEFT LIFT (N)	3738.06	-3996.23	-2014.06	701.91	-34.85
TOP TENSION (N)	-29.97	-5230.38	-1748.33	796.68	-45.57
ENGINE RPM	1995.72	1934.83	1965.38	11.68	0.59
PTO RPM	567.21	549.90	558.58	3.42	0.61
WHEEL SPEED (Km/h)	4.60	4.27	4.44	0.06	1.38
GROUND SPEED (Km/h)	4.19	3.75	3.97	0.09	2.14
TORQUE (N-M)	584.46	195.00	435.05	59.63	13.71
NET DRAFT (N)	27103.70	-8125.41	8959.89	5637.63	62.92
NET LIFT (N)	3083.94	-2112.88	72.55	775.02	1068.19
SLIPPAGE (%)	15.67	5.12	10.59	2.00	18.83
DRAW POWER (Kw)	29.70	-8.99	9.91	6.27	63.24
PTO POWER (Kw)	34.43	11.40	25.45	3.48	13.69
TOTAL POWER (Kw)	56.33	12.80	35.36	6.58	18.61
DISK SPEED (Km/h)	14.65	14.20	14.43	0.09	0.65
PDV/GS RATIO	3.84	3.46	3.63	0.07	2.02

T5.L04.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =13.97CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	11678.00	-4035.87	1869.37	2307.95	123.46
LEFT DRAFT (N)	9805.31	-16692.60	854.54	3167.48	370.67
RIGHT LIFT (N)	6636.83	-114.09	2280.41	921.82	40.42
LEFT LIFT (N)	-301.59	-6370.33	-2592.28	588.18	-22.69
TOP TENSION (N)	-367.66	-7984.42	-2813.06	816.18	-29.01
ENGINE RPM	2022.78	1827.81	1961.75	42.93	2.19
PTO RPM	574.90	519.48	557.55	12.17	2.18
WHEEL SPEED (Km/h)	6.62	5.81	6.34	0.15	2.41
GROUND SPEED (Km/h)	6.00	5.03	5.62	0.21	3.80
TORQUE (N-M)	596.03	114.02	411.12	54.50	13.26
NET DRAFT (N)	12488.00	-11898.20	2723.91	3798.62	139.46
NET LIFT (N)	1870.84	-2526.83	-311.88	763.78	-244.90
SLIPPAGE (%)	20.86	6.05	11.42	2.78	24.39
DRAW POWER (Kw)	19.29	-18.84	4.24	5.93	139.90
PTO POWER (Kw)	35.64	6.62	24.00	3.17	13.20
TOTAL POWER (Kw)	46.32	-0.48	28.24	6.86	24.29
DISK SPEED (Km/h)	14.85	13.42	14.40	0.32	2.19
PDV/GS RATIO	2.86	2.43	2.56	0.08	3.13

T6.L04.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =12.7CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	7490.72	-8558.03	-835.97	2030.16	-242.85
LEFT DRAFT (N)	16114.50	-19731.00	-1742.52	3433.62	-197.05
RIGHT LIFT (N)	4365.48	-2237.84	2343.01	855.87	36.53
LEFT LIFT (N)	1665.10	-6817.84	-2714.59	667.52	-24.59
TOP TENSION (N)	-225.08	-6483.58	-2410.81	896.00	-37.17
ENGINE RPM	1971.12	1944.06	1955.89	4.77	0.24
PTO RPM	560.21	552.52	555.88	1.58	0.28
WHEEL SPEED (Km/h)	6.70	6.33	6.51	0.06	0.87
GROUND SPEED (Km/h)	5.95	5.46	5.74	0.09	1.59
TORQUE (N-M)	601.82	77.39	411.17	54.79	13.33
NET DRAFT (N)	17035.00	-28289.00	-2578.49	4239.93	-164.44
NET LIFT (N)	1607.28	-2678.18	-371.58	741.65	-199.60
SLIPPAGE (%)	16.30	8.44	11.83	1.41	11.94
DRAW POWER (Kw)	26.92	-44.30	-4.13	6.76	-163.77
PTO POWER (Kw)	34.89	4.49	23.93	3.17	13.26
TOTAL POWER (Kw)	43.00	-26.96	19.81	7.16	36.16
DISK SPEED (Km/h)	14.47	14.27	14.36	0.04	0.27
PDV/GS RATIO	2.63	2.42	2.50	0.04	1.49

T7.L01.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =26.67CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	23298.80	-2683.49	2692.34	2875.28	106.80
LEFT DRAFT (N)	18156.90	3263.74	12545.90	2524.77	20.12
RIGHT LIFT (N)	3136.06	-162.85	869.15	541.25	62.27
LEFT LIFT (N)	480.99	-2871.35	-713.05	534.11	-74.90
TOP TENSION (N)	1035.63	-4134.77	-1028.23	596.48	-58.01
ENGINE RPM	2128.57	2101.51	2113.79	4.78	0.23
PTO RPM	1033.29	1020.15	1026.11	2.53	0.25
WHEEL SPEED (Km/h)	2.34	2.11	2.22	0.05	2.36
GROUND SPEED (Km/h)	2.04	1.82	1.93	0.05	2.50
TORQUE (N-M)	507.34	281.76	407.46	36.96	9.07
NET DRAFT (N)	37578.20	1550.92	15238.30	4347.98	28.53
NET LIFT (N)	2680.87	-1611.35	156.10	488.68	313.06
SLIPPAGE (%)	19.79	5.91	12.91	2.82	21.86
DRAW POWER (Kw)	20.50	0.80	8.17	2.33	28.49
PTO POWER (Kw)	54.64	30.29	43.78	3.96	9.05
TOTAL POWER (Kw)	67.92	36.98	51.95	4.64	8.92
DISK SPEED (Km/h)	26.69	26.35	26.50	0.06	0.23
PDV/GS RATIO	14.59	12.96	13.73	0.34	2.47

T8.L01.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =30.48CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	17059.20	-2667.26	2860.30	2836.07	99.15
LEFT DRAFT (N)	16750.10	2570.39	11814.80	2457.11	20.80
RIGHT LIFT (N)	3345.12	1.62	1044.68	699.90	67.00
LEFT LIFT (N)	769.78	-2929.53	-737.95	610.71	-82.76
TOP TENSION (N)	517.84	-4877.68	-1138.31	713.72	-62.70
ENGINE RPM	2110.12	2083.06	2098.26	5.33	0.25
PTO RPM	1024.33	1011.19	1018.57	2.87	0.28
WHEEL SPEED (Km/h)	2.33	2.09	2.20	0.05	2.36
GROUND SPEED (Km/h)	2.12	1.87	1.99	0.05	2.70
TORQUE (N-M)	561.33	293.33	405.66	42.62	10.51
NET DRAFT (N)	33031.80	1209.32	14675.10	3888.64	26.50
NET LIFT (N)	2215.35	-1206.98	306.73	545.08	177.71
SLIPPAGE (%)	16.74	1.35	9.56	2.90	30.34
DRAW POWER (Kw)	18.01	0.70	8.12	2.15	26.47
PTO POWER (Kw)	59.97	31.24	43.27	4.50	10.40
TOTAL POWER (Kw)	68.08	36.71	51.38	4.86	9.46
DISK SPEED (Km/h)	26.45	26.12	26.31	0.07	0.28
PDV/GS RATIO	14.07	12.42	13.21	0.36	2.69

T9.L03.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =21.59CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	9777.14	-6517.17	874.11	2992.64	342.36
LEFT DRAFT (N)	20136.40	-12930.70	5604.40	4087.00	72.92
RIGHT LIFT (N)	5562.23	-873.19	1945.54	994.30	51.11
LEFT LIFT (N)	1158.20	-6456.10	-1782.97	856.08	-48.01
TOP TENSION (N)	1283.27	-7871.86	-1172.12	902.09	-76.96
ENGINE RPM	2127.34	2065.22	2092.07	18.68	0.89
PTO RPM	1032.69	1002.53	1015.57	8.89	0.88
WHEEL SPEED (Km/h)	4.98	4.62	4.80	0.07	1.50
GROUND SPEED (Km/h)	4.39	4.05	4.21	0.07	1.58
TORQUE (N-M)	603.75	129.44	401.65	56.42	14.05
NET DRAFT (N)	19999.40	-18237.50	6478.51	5167.21	79.76
NET LIFT (N)	2276.44	-3069.35	162.57	795.68	489.44
SLIPPAGE (%)	17.72	7.17	12.26	1.65	13.49
DRAW POWER (Kw)	23.82	-20.50	7.58	6.05	79.78
PTO POWER (Kw)	63.91	13.62	42.70	5.93	13.89
TOTAL POWER (Kw)	77.34	10.21	50.28	8.86	17.61
DISK SPEED (Km/h)	26.67	25.89	26.23	0.23	0.89
PDV/GS RATIO	6.50	5.92	6.23	0.11	1.72

T10.L03.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =21.59CM.10/16/85

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	5948.40	-6878.64	-1349.87	2387.43	-176.86
LEFT DRAFT (N)	15453.80	-5199.61	6786.12	3622.77	53.39
RIGHT LIFT (N)	3432.33	-600.73	1012.79	829.99	81.95
LEFT LIFT (N)	419.64	-3416.08	-1230.10	763.25	-62.05
TOP TENSION (N)	878.04	-3504.41	-1049.19	728.95	-69.48
ENGINE RPM	2124.88	1835.81	2049.43	80.01	3.90
PTO RPM	1031.50	891.17	994.87	38.86	3.91
WHEEL SPEED (Km/h)	4.95	4.11	4.70	0.20	4.21
GROUND SPEED (Km/h)	4.34	2.73	3.87	0.43	11.04
TORQUE (N-M)	549.76	218.13	376.25	60.03	15.96
NET DRAFT (N)	18543.10	-9031.19	5436.25	4080.05	75.05
NET LIFT (N)	1736.40	-1868.75	-217.31	586.10	-269.71
SLIPPAGE (%)	38.31	8.35	17.82	6.97	39.13
DRAW POWER (Kw)	21.44	-10.52	5.84	4.47	76.58
PTO POWER (Kw)	55.74	22.83	39.11	5.84	14.93
TOTAL POWER (Kw)	65.77	26.04	44.95	6.76	15.04
DISK SPEED (Km/h)	26.64	23.02	25.69	1.00	3.91
PDV/GS RATIO	8.81	6.07	6.71	0.64	9.53

T11.L04.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =17.78CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	13125.30	-6600.87	965.30	3506.80	363.29
LEFT DRAFT (N)	12422.90	-16131.10	1758.22	4244.10	241.39
RIGHT LIFT (N)	7034.22	-497.28	2254.77	1296.43	57.50
LEFT LIFT (N)	609.71	-6355.86	-2345.55	912.28	-38.89
TOP TENSION (N)	315.23	-8209.55	-1558.71	1073.47	-68.87
ENGINE RPM	2162.40	2003.10	2122.68	30.59	1.44
PTO RPM	1049.71	972.38	1030.42	14.86	1.44
WHEEL SPEED (Km/h)	7.25	6.63	7.07	0.11	1.53
GROUND SPEED (Km/h)	6.47	5.60	6.12	0.18	2.89
TORQUE (N-M)	628.81	187.29	423.91	62.70	14.79
NET DRAFT (N)	14242.40	-13406.60	2723.52	4401.13	161.60
NET LIFT (N)	2658.68	-2738.73	-90.78	895.15	-986.07
SLIPPAGE (%)	21.27	9.55	13.47	2.33	17.29
DRAW POWER (Kw)	25.04	-23.21	4.64	7.46	160.86
PTO POWER (Kw)	68.93	20.40	45.71	6.55	14.34
TOTAL POWER (Kw)	87.84	19.11	50.35	10.43	20.72
DISK SPEED (Km/h)	27.11	25.11	26.61	0.38	1.44
PDV/GS RATIO	4.76	4.15	4.35	0.11	2.62

T1.L04.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =17.78CM.10/17/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	9908.52	-6464.35	1645.16	2996.18	182.12
LEFT DRAFT (N)	11730.90	-11272.70	-279.60	3484.47	-1246.22
RIGHT LIFT (N)	5054.65	-1057.97	2599.65	993.78	38.23
LEFT LIFT (N)	-64.65	-5089.90	-2952.71	689.15	-23.34
TOP TENSION (N)	1395.83	-5350.45	-1154.74	915.89	-79.32
ENGINE RPM	2178.39	1916.38	2136.05	52.28	2.45
PTO RPM	1057.47	930.28	1036.92	25.36	2.45
WHEEL SPEED (Km/h)	7.18	6.16	6.95	0.18	2.61
GROUND SPEED (Km/h)	6.65	5.61	6.31	0.20	3.23
TORQUE (N-M)	671.23	247.06	479.17	73.57	15.35
NET DRAFT (N)	12883.00	-10747.80	1365.55	3920.60	287.11
NET LIFT (N)	1744.07	-2945.30	-353.06	815.92	-231.10
SLIPPAGE (%)	15.10	5.10	9.12	1.89	20.76
DRAW POWER (Kw)	23.57	-19.26	2.43	6.90	284.48
PTO POWER (Kw)	72.96	27.02	51.95	7.54	14.52
TOTAL POWER (Kw)	81.80	21.19	54.38	10.16	18.68
DISK SPEED (Km/h)	27.31	24.03	26.78	0.66	2.45
PDV/GS RATIO	4.46	4.07	4.24	0.08	1.92

T3.L01.(TW10).SWINE BARN FIELD.SOIL M C=16%.DEPTH =19.05CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	13553.40	-7180.66	1034.35	3855.96	372.79
LEFT DRAFT (N)	14701.40	-11423.40	4940.90	3304.33	66.88
RIGHT LIFT (N)	4560.10	-498.36	1471.98	796.66	54.12
LEFT LIFT (N)	152.10	-5825.30	-1896.05	644.87	-34.01
TOP TENSION (N)	938.07	-6761.24	-566.52	741.48	-130.88
ENGINE RPM	1624.84	1595.32	1610.21	5.54	0.34
PTO RPM	788.76	774.43	781.65	2.79	0.36
WHEEL SPEED (Km/h)	3.17	2.81	2.97	0.06	2.09
GROUND SPEED (Km/h)	2.94	2.65	2.78	0.06	1.99
TORQUE (N-M)	509.27	164.15	385.03	46.00	11.95
NET DRAFT (N)	21398.00	-8875.01	5975.25	5768.69	96.54
NET LIFT (N)	1779.41	-2546.11	-424.07	820.15	-193.40
SLIPPAGE (%)	11.87	0.77	6.35	2.09	32.98
DRAW POWER (Kw)	16.02	-6.93	4.60	4.44	96.55
PTO POWER (Kw)	42.02	13.48	31.51	3.73	11.84
TOTAL POWER (Kw)	53.44	9.77	36.12	6.06	16.78
DISK SPEED (Km/h)	20.37	20.00	20.19	0.07	0.34
PDV/GS RATIO	7.67	6.85	7.27	0.14	1.95

T4.L03(TW10).SWINE BARN FIELD.SOIL M C=16%.DEPTH =15.24CM.10/17/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	13547.50	-7816.24	2259.39	3540.24	156.69
LEFT DRAFT (N)	8404.80	-19918.20	-205.91	3701.55	-1797.67
RIGHT LIFT (N)	8010.00	-898.69	2336.48	1015.30	43.45
LEFT LIFT (N)	-432.58	-8246.29	-2744.29	698.15	-25.44
TOP TENSION (N)	727.96	-7106.43	-1018.38	818.62	-80.38
ENGINE RPM	1769.38	1535.05	1616.84	61.68	3.81
PTO RPM	858.92	745.17	784.87	29.99	3.82
WHEEL SPEED (Km/h)	6.24	5.85	6.07	0.06	1.02
GROUND SPEED (Km/h)	5.89	5.61	5.76	0.05	0.95
TORQUE (N-M)	584.46	193.07	411.52	54.85	13.33
NET DRAFT (N)	12980.50	-14718.50	2053.48	4564.54	222.28
NET LIFT (N)	1876.30	-2912.59	-407.81	887.53	-217.63
SLIPPAGE (%)	8.10	2.01	5.09	1.01	19.80
DRAW POWER (Kw)	20.63	-23.81	3.28	7.31	222.70
PTO POWER (Kw)	47.73	17.17	33.77	4.30	12.74
TOTAL POWER (Kw)	58.47	3.48	37.05	8.42	22.71
DISK SPEED (Km/h)	22.18	19.24	20.27	0.77	3.82
PDV/GS RATIO	3.89	3.32	3.52	0.14	3.90

T5.L03.(TW10).SWINE BARN FIELD.SOIL M C=16%.TILLAGE DEPTH =12.70CM.10/17/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	13604.50	-6661.90	3851.77	3574.67	92.81
LEFT DRAFT (N)	14935.10	-13316.30	-1295.31	4527.05	-349.50
RIGHT LIFT (N)	5701.07	-905.07	2759.96	1064.52	38.57
LEFT LIFT (N)	867.00	-5673.37	-3112.49	830.09	-26.67
TOP TENSION (N)	-14.96	-4457.45	-1251.77	758.35	-60.58
ENGINE RPM	1653.14	1602.09	1625.07	9.79	0.60
PTO RPM	802.49	777.71	788.87	4.74	0.60
WHEEL SPEED (Km/h)	6.34	5.72	6.11	0.14	2.28
GROUND SPEED (Km/h)	6.01	5.41	5.79	0.14	2.42
TORQUE (N-M)	655.80	100.52	411.35	65.55	15.94
NET DRAFT (N)	20882.60	-15435.00	2556.46	5693.47	222.71
NET LIFT (N)	2609.45	-3670.68	-352.53	996.40	-282.64
SLIPPAGE (%)	8.08	2.44	5.24	1.02	19.41
DRAW POWER (Kw)	32.85	-25.63	4.06	9.12	224.50
PTO POWER (Kw)	54.29	8.34	33.97	5.34	15.73
TOTAL POWER (Kw)	74.18	6.13	38.03	9.76	25.67
DISK SPEED (Km/h)	20.73	20.09	20.37	0.13	0.63
PDV/GS RATIO	3.81	3.37	3.52	0.10	2.81

T6.L04(TW10).SWINE BARN FIELD.SOIL M C =16%.DEPTH =12.7CM.10/17/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	15739.30	-6040.95	4032.42	3856.30	95.63
LEFT DRAFT (N)	15818.10	-38641.00	-3496.83	4914.92	-140.55
RIGHT LIFT (N)	9289.61	-458.91	3123.66	1203.80	38.54
LEFT LIFT (N)	667.89	-12698.20	-3541.02	1014.46	-28.65
TOP TENSION (N)	1388.33	-13455.00	-1824.48	1093.65	-59.94
ENGINE RPM	1638.99	1592.25	1611.36	9.39	0.58
PTO RPM	795.63	772.94	782.21	4.64	0.59
WHEEL SPEED (Km/h)	8.59	7.48	8.15	0.22	2.68
GROUND SPEED (Km/h)	8.09	7.07	7.73	0.20	2.60
TORQUE (N-M)	586.39	17.62	424.44	60.66	14.29
NET DRAFT (N)	22571.30	-29612.10	535.59	5012.06	935.80
NET LIFT (N)	1993.26	-3503.99	-417.36	984.84	-235.97
SLIPPAGE (%)	7.40	2.82	5.25	0.75	14.25
DRAW POWER (Kw)	49.54	-65.15	1.13	10.77	950.88
PTO POWER (Kw)	47.98	1.44	34.76	4.91	14.13
TOTAL POWER (Kw)	77.89	-42.31	35.89	11.18	31.15
DISK SPEED (Km/h)	20.55	19.96	20.20	0.12	0.61
PDV/GS RATIO	2.83	2.50	2.62	0.07	2.75

T7.L04.(TW10).SWINE BARN FIELD.SOIL M C=16%.DEPTH =12.7CM.10/17/85

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	19420.50	-5319.60	4411.06	4128.46	93.59
LEFT DRAFT (N)	9257.67	-20126.70	-5062.72	5158.50	-101.89
RIGHT LIFT (N)	7899.76	-1022.00	3268.23	1300.92	39.81
LEFT LIFT (N)	387.99	-7143.87	-3747.43	879.61	-23.47
TOP TENSION (N)	1966.15	-4720.10	-1339.09	1046.85	-78.18
ENGINE RPM	1673.43	1563.34	1614.50	31.48	1.95
PTO RPM	812.35	758.90	783.74	15.32	1.95
WHEEL SPEED (Km/h)	8.35	7.40	7.90	0.23	2.96
GROUND SPEED (Km/h)	8.02	6.98	7.52	0.24	3.22
TORQUE (N-M)	725.21	218.13	467.70	83.08	17.76
NET DRAFT (N)	21531.80	-14639.50	-651.65	6308.76	-968.12
NET LIFT (N)	4000.88	-3839.34	-479.19	1265.85	-264.16
SLIPPAGE (%)	7.84	2.55	4.91	0.87	17.72
DRAW POWER (Kw)	42.38	-31.28	-1.46	13.19	-903.02
PTO POWER (Kw)	59.94	18.04	38.41	7.00	18.22
TOTAL POWER (Kw)	85.53	-6.32	36.95	13.79	37.33
DISK SPEED (Km/h)	20.98	19.60	20.24	0.39	1.95
PDV/GS RATIO	2.96	2.50	2.70	0.12	4.29

T1.L01.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH=21.59CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	20810.30	-7507.49	2541.66	5051.23	198.74
LEFT DRAFT (N)	14676.30	3084.12	10005.40	2291.48	22.90
RIGHT LIFT (N)	3886.85	-388.39	1432.15	841.74	58.77
LEFT LIFT (N)	46.29	-2515.78	-1106.98	547.31	-49.44
TOP TENSION (N)	953.08	-4007.20	-395.97	497.18	-125.56
ENGINE RPM	1976.04	1926.22	1952.71	11.30	0.58
PTO RPM	561.61	547.45	554.98	3.15	0.57
WHEEL SPEED (Km/h)	2.14	1.83	2.02	0.05	2.61
GROUND SPEED (Km/h)	1.98	1.72	1.86	0.05	2.84
TORQUE (N-M)	592.18	339.60	476.31	39.95	8.39
NET DRAFT (N)	33725.60	-2611.32	12547.10	5638.15	44.94
NET LIFT (N)	2436.08	-1487.42	325.18	668.25	205.50
SLIPPAGE (%)	16.82	-0.40	8.15	3.12	38.23
DRAW POWER (Kw)	17.61	-1.31	6.47	2.92	45.15
PTO POWER (Kw)	34.00	19.83	27.68	2.29	8.29
TOTAL POWER (Kw)	47.62	20.53	34.15	3.70	10.83
DISK SPEED (Km/h)	14.50	14.14	14.33	0.08	0.58
PDV/GS RATIO	8.24	7.28	7.73	0.21	2.71

T2.L01.SWINE BARN FIELD.SOIL M C =16%.TILLAGE DEPTH =21.59CM.10/16/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	14580.20	-5170.03	-112.90	3404.66	-3015.67
LEFT DRAFT (N)	18146.80	4297.48	12056.20	2700.88	22.40
RIGHT LIFT (N)	3780.74	-365.54	634.38	871.65	137.40
LEFT LIFT (N)	385.12	-2282.76	-799.78	556.76	-69.61
TOP TENSION (N)	555.36	-2956.61	-1158.89	586.52	-50.61
ENGINE RPM	2011.10	1937.90	1977.17	14.69	0.74
PTO RPM	571.58	550.77	561.93	4.12	0.73
WHEEL SPEED (Km/h)	2.16	1.87	2.01	0.05	2.72
GROUND SPEED (Km/h)	1.96	1.67	1.82	0.05	3.01
TORQUE (N-M)	613.39	291.40	427.78	54.24	12.68
NET DRAFT (N)	23848.30	1415.99	11943.30	3513.07	29.41
NET LIFT (N)	2054.93	-1153.39	-165.40	519.43	-314.05
SLIPPAGE (%)	17.57	0.47	9.51	3.18	33.43
DRAW POWER (Kw)	11.68	0.73	6.03	1.78	29.50
PTO POWER (Kw)	35.57	17.23	25.16	3.07	12.18
TOTAL POWER (Kw)	43.81	22.23	31.19	3.75	12.02
DISK SPEED (Km/h)	14.76	14.22	14.51	0.11	0.72
PDV/GS RATIO	8.62	7.47	7.99	0.23	2.93

L03.(TW10).PTO DISENGAGED.SWINE BARN FIELD.M C=16%.DEPTH =5.08CM.10/17/85.

	MAXIMUM	MINIMUM	AVERAGE	STD. DEV.	COEF. VAR.
RIGHT DRAFT (N)	8475.38	-4704.90	464.82	2210.55	475.57
LEFT DRAFT (N)	16758.90	873.45	10446.50	2624.52	25.12
RIGHT LIFT (N)	2064.95	-2048.79	-874.24	554.31	-63.41
LEFT LIFT (N)	1681.68	-2176.64	-227.18	549.26	-241.77
TOP TENSION (N)	-7841.84	-12554.50	-9765.09	793.13	-8.12
ENGINE RPM	2212.22	2075.68	2139.10	46.04	2.15
PTO RPM	0.00	0.00	0.00	0.00	0.00
WHEEL SPEED (Km/h)	5.09	4.72	4.86	0.10	2.10
GROUND SPEED (Km/h)	4.28	3.68	3.91	0.12	3.07
TORQUE (N-M)	0.00	0.00	0.00	0.00	0.00
NET DRAFT (N)	16796.60	1134.19	10911.30	2842.87	26.05
NET LIFT (N)	80.25	-2562.05	-1101.42	552.99	-50.21
SLIPPAGE (%)	23.10	11.91	19.55	1.77	9.05
DRAW POWER (Kw)	19.36	1.26	11.88	3.19	26.84
PTO POWER (Kw)	0.00	0.00	0.00	0.00	0.00
TOTAL POWER (Kw)	19.36	1.26	11.88	3.19	26.84
DISK SPEED (Km/h)	4.28	3.68	3.91	0.12	3.07
PDV/GS RATIO	1.00	1.00	1.00	0.00	0.00

APPENDIX E

APPENDIX E : RAW DATA PRINTOUT

The printout shows the numerical values of the parameters instrumented. These values were collected in ASCII code, then converted into Voltages and finally into the present form using the calibration response equations.

The negative horizontal force values indicate that the implement was pushing the tractor 3-point-hitch in the direction of travel and the positive values indicate that the implement was pulling on the 3-point-hitch; in the opposite direction to forward travel.

Negative vertical forces indicate that the implement was pushing the tractor 3-point-hitch vertically upwards and positive vertical forces indicate that the tractor 3-point-hitch was pushing the implement vertically downwards; aiding penetration.

Negative PTO torque indicates that the torquemeter was loaded in the opposite operating rotational direction during calibration. The negative sign is software corrected and should be ignored.

In the printout:

Channel 1 was the Right Horizontal Force (N)

Channel 2 was the Left Horizontal Force (N)

Channel 3 was the Right Vertical Force (N)

Channel 4 was the Left Vertical Force (N)

Channel 5 was the Top Link Force (N)

Channel 6 was the Engine Speed (RPM)

Channel 8 was the Rear Wheel Speed (Km/h)

Channel 9 was the Rront Wheel (Ground) Speed (Km/h)

Channel 10 was the PTO Torque (Nm)

There were 19 such printouts for the field tests carried out and Appendix D lists the analytical summary of these tests.

LO.ONE.540 RPM.SOIL MOISTURE=16%.SANDY LOAM.SWINE BARN FIELD.

CH. 1	CH. 2	CH. 3	CH. 4	CH. 5	CH. 6	CH. 8	CH. 9	CH. 10
8996.32	8810.51	2329.61	-1602.22	-600.29	1976.04	2.04	1.94	-515.05
13497.60	7946.34	3146.22	-1821.98	-525.25	1972.35	1.95	1.94	-505.41
2988.90	8623.36	2202.99	-1727.47	-615.30	1968.66	1.98	1.80	-488.06
11815.70	6820.91	2853.97	-2199.10	-742.87	1971.12	2.00	1.82	-545.90
9920.17	7760.44	2639.52	-1917.24	-570.27	1966.81	2.01	1.84	-501.56
10100.40	8251.56	2500.08	-1917.99	-592.78	1967.43	2.04	1.89	-449.50
11042.40	8515.33	2821.43	-1700.65	-577.78	1968.04	2.07	1.89	-466.85
7144.77	8991.38	2558.31	-1626.94	-600.29	1963.12	2.07	1.90	-507.34
5118.42	8055.62	2585.45	-1818.82	-585.28	1963.12	2.09	1.91	-503.49
9627.85	9008.97	2758.83	-1641.41	-540.25	1962.51	1.94	1.94	-511.20
11100.10	9158.44	2807.26	-1547.20	-532.75	1961.28	1.96	1.85	-505.41
7580.43	9010.22	2286.39	-1611.41	-495.23	1961.89	1.97	1.80	-518.91
6058.69	10278.80	2135.81	-1290.06	-502.73	1958.82	2.00	1.83	-518.91
8294.56	10155.80	2089.03	-1188.77	-457.71	1958.82	2.02	1.85	-463.00
11797.50	10724.70	2579.08	-1067.44	-240.09	1961.28	2.03	1.89	-484.21
9778.12	9898.26	2509.29	-1256.15	-412.68	1958.82	2.07	1.91	-468.78
9870.50	10737.30	2010.46	-1201.89	-532.75	1961.28	2.09	1.92	-503.49
7463.89	10694.60	1534.05	-1352.92	-615.30	1958.82	2.11	1.94	-503.49
9587.78	11268.60	1730.60	-1111.60	-600.29	1958.82	1.96	1.91	-501.56
8243.02	9305.40	2015.96	-1512.99	-622.80	1958.82	1.96	1.81	-530.48
5620.75	9186.07	1909.89	-1756.11	-1275.67	1955.74	2.00	1.84	-518.91
3131.24	10857.90	1269.70	-1363.17	-727.86	1956.97	2.02	1.85	-495.77
3693.02	10682.00	1350.96	-1218.47	-622.80	1956.97	2.01	1.87	-476.49
6903.00	10042.70	1970.01	-1281.92	-532.75	1954.51	2.05	1.90	-524.70
884.88	9704.83	1198.42	-1531.38	-585.28	1953.90	2.08	1.92	-540.12
-4896.51	9760.09	556.06	-1514.80	-1260.66	1955.74	2.09	1.92	-513.13
-2579.82	10036.40	702.15	-1431.90	-825.41	1949.59	1.95	1.92	-522.77
-2648.08	11307.60	598.26	-1050.56	-540.25	1950.21	1.96	1.81	-540.12
1182.64	11291.20	738.11	-1006.09	-990.51	1950.21	1.97	1.82	-518.91
-45.89	10555.20	985.44	-1207.16	-915.46	1947.75	2.00	1.85	-536.26
804.75	10886.80	995.86	-1107.68	-592.78	1948.98	2.01	1.87	-464.93
1644.22	12743.20	897.91	-649.47	-540.25	1952.05	2.02	1.87	-516.98
10662.00	12686.70	2054.43	-696.05	-532.75	1947.75	2.07	1.91	-507.34
8734.27	11767.30	1495.50	-932.39	-630.31	1950.21	2.09	1.94	-532.41
10571.50	11430.70	1997.27	-1151.85	-577.78	1950.21	1.93	1.78	-515.05
11661.70	10512.50	2361.61	-1358.19	-540.25	1948.98	1.96	1.82	-507.34
6320.93	10256.20	1642.94	-1395.57	-1080.56	1951.44	1.97	1.83	-499.63
9750.81	11262.30	2096.95	-1261.58	-660.32	1948.36	2.02	1.87	-542.05
10744.90	11187.00	2218.22	-1323.68	-802.90	1952.67	2.02	1.87	-511.20
10670.50	9076.79	2465.03	-1759.28	-862.94	1953.28	2.04	1.89	-441.79
8265.38	9369.46	2232.69	-1720.84	-877.94	1953.28	2.07	1.92	-434.08
12651.80	8811.77	3067.95	-2006.62	-562.77	1955.74	2.08	1.94	-505.41
9995.25	10517.50	2383.02	-1672.61	-1133.09	1953.90	2.09	1.82	-507.34
-542.78	11350.30	1319.99	-1333.93	-540.25	1956.36	1.94	1.82	-476.49
1890.94	11127.90	1681.81	-1430.24	-457.71	1953.28	1.96	1.84	-530.48
4015.52	9238.83	1868.67	-1799.52	-1313.19	1956.97	1.98	1.86	-524.70
4553.77	10118.10	2279.50	-1654.22	-592.78	1955.74	2.01	1.87	-511.20
1976.02	11630.40	2079.98	-1161.04	-532.75	1957.59	2.04	1.91	-513.13
16722.10	11526.10	3298.26	-1478.62	-480.22	1958.82	2.05	1.92	-428.29
14836.20	10187.20	2948.10	-1742.10	-900.46	1956.97	2.07	1.95	-420.58
14213.30	10179.60	3192.93	-1487.67	-517.74	1958.82	2.07	1.78	-488.06
12754.90	9015.25	3214.09	-1925.83	-502.73	1958.82	2.08	1.82	-540.12
13680.50	11345.20	2704.55	-1453.90	-675.33	1960.66	1.93	1.82	-457.21
14499.80	11274.90	2624.26	-1396.03	-847.93	1958.82	1.96	1.86	-488.06
12592.50	11259.80	2574.59	-1321.57	-795.40	1963.12	1.98	1.85	-476.49
12837.60	10508.70	2850.97	-1448.18	-592.78	1963.12	2.02	1.89	-518.91
12898.90	10391.90	2788.33	-1631.31	-577.78	1964.97	2.01	1.91	-493.85
12747.00	12028.50	2530.35	-1209.42	-592.78	1966.20	2.06	1.96	-443.72
20010.60	12139.10	3612.34	-1176.26	-570.27	1965.58	2.07	1.79	-426.36
15416.10	10999.80	3040.80	-1448.93	-547.76	1965.58	2.11	1.83	-480.35
10698.30	10356.70	2340.75	-1602.37	-735.36	1966.81	1.93	1.83	-499.63
8855.55	12086.30	1916.53	-1132.85	-705.35	1963.74	1.96	1.87	-491.92
13104.90	10466.00	2817.16	-1599.21	-1005.51	1965.58	1.99	1.87	-457.21
10542.50	11222.10	2667.84	-1352.62	-577.78	1963.74	2.02	1.91	-464.93
8625.95	11444.50	2217.27	-1256.30	-592.78	1966.81	2.02	1.93	-480.35
4788.01	12195.60	1383.99	-1129.69	-727.86	1963.12	2.05	1.91	-453.36
6787.35	11570.10	1734.89	-1297.60	-960.49	1964.35	2.07	1.80	-416.72
5423.00	10579.00	1764.75	-1506.06	-900.46	1963.74	2.07	1.83	-453.36
4275.09	11058.90	1678.03	-1342.37	-712.85	1966.20	2.11	1.85	-513.13
-1186.08	10688.30	1055.55	-1502.89	-1313.19	1964.97	1.94	1.85	-430.22
2417.80	11683.10	1457.37	-1204.45	-600.29	1965.58	1.98	1.89	-470.71
5608.29	9993.72	2084.37	-1582.93	-847.93	1965.58	1.99	1.91	-466.85
720.67	11154.30	1378.37	-1234.75	-765.38	1966.81	2.02	1.94	-491.92

-260.95	12352.60	1082.62	-855.52	-517.74	1968.04	2.02	1.89	-472.64
1604.85	11204.60	1713.88	-1338.15	-495.23	1966.81	2.05	1.82	-476.49
2023.30	11355.30	1947.75	-1213.95	-517.74	1967.43	2.06	1.82	-463.00
2043.48	9596.80	1930.11	-1504.55	-502.73	1966.81	2.09	1.87	-422.51
5137.02	9954.78	2060.27	-1643.97	-577.78	1968.04	2.11	1.87	-428.29
12385.00	11433.20	2565.15	-1091.86	-487.73	1967.43	1.96	1.89	-484.21
11445.40	10919.40	2741.64	-1196.61	-480.22	1968.66	1.96	1.90	-489.99
13182.30	10005.00	3058.49	-1312.97	-555.26	1968.04	2.00	1.93	-451.43
3013.92	9944.73	2117.49	-1449.53	-495.23	1968.66	2.01	1.94	-486.13
2321.26	10516.20	2014.36	-1268.21	-375.16	1968.04	2.04	1.81	-488.06
3790.87	11286.20	2365.02	-1126.07	-442.70	1968.66	2.04	1.82	-489.99
3125.31	10792.60	2147.31	-1185.31	-382.67	1968.66	2.07	1.85	-488.06
5337.54	9196.12	2166.65	-1516.15	-540.25	1969.27	2.07	1.87	-439.86
4997.83	10350.40	2154.72	-1317.95	-532.75	1969.89	2.11	1.91	-414.80
4653.98	10168.30	2200.96	-1323.22	-547.76	1971.12	1.95	1.91	-449.50
241.68	9159.70	1197.44	-1517.21	-502.73	1969.89	1.98	1.92	-457.21
5228.23	9214.96	2107.74	-1500.63	-495.23	1969.89	2.00	1.93	-461.07
3313.06	11501.00	1637.79	-1209.73	-525.25	1971.73	2.02	1.96	-449.50
3582.53	12670.40	1838.36	-651.58	-307.62	1968.66	2.04	1.82	-439.86
1742.75	10056.50	1902.28	-1386.38	-540.25	1972.35	2.04	1.84	-472.64
9988.23	10335.40	2216.50	-1243.49	-465.21	1972.35	2.07	1.87	-480.35
-2224.78	11254.80	764.28	-1007.15	-532.75	1974.19	2.08	1.87	-432.15
4031.93	12448.10	1109.12	-747.90	-562.77	1972.96	2.11	1.91	-441.79
1697.24	11052.60	1215.05	-1057.94	-547.76	1975.42	2.11	1.91	-447.57
8828.45	10585.30	2031.11	-1356.08	-577.78	1973.58	1.98	1.93	-470.71
3944.39	8604.52	1540.10	-1743.00	-720.36	1974.81	2.00	1.94	-526.62
7972.06	11381.70	1571.32	-1018.45	-652.82	1972.35	2.02	1.92	-443.72
7220.93	12725.70	1492.05	-635.00	-547.76	1973.58	2.02	1.81	-434.08
5731.94	12665.40	1412.80	-771.56	-532.75	1970.50	2.04	1.85	-511.20
5601.85	10494.90	1644.70	-1343.72	-630.31	1972.35	2.05	1.85	-532.41
7056.72	12796.00	1672.00	-692.88	-540.25	1969.27	2.09	1.89	-464.93
3136.19	13189.10	1465.30	-426.85	-150.04	1973.58	2.11	1.91	-455.29
119.91	11639.20	1313.01	-951.08	-502.73	1968.66	2.14	1.92	-488.06
11413.90	11346.50	2387.46	-989.51	-532.75	1969.89	1.98	1.94	-501.56
731.16	11254.80	1496.43	-1007.15	-397.67	1968.66	1.98	1.96	-491.92
2135.08	10723.50	1177.51	-1097.43	-510.24	1965.58	2.01	1.82	-437.93
4237.40	11306.30	1411.09	-1080.55	-615.30	1967.43	2.02	1.82	-445.64
1856.71	12224.50	1366.41	-874.21	-570.27	1964.97	2.04	1.87	-484.21
359.40	10244.90	1403.48	-1231.13	-547.76	1968.04	2.05	1.87	-518.91
1198.28	9434.77	1578.68	-1464.30	-592.78	1964.35	2.09	1.89	-463.00
10584.00	10516.20	2086.25	-1268.21	-510.24	1966.81	2.11	1.91	-426.36
318.35	10916.90	1448.47	-1256.60	-577.78	1966.20	2.04	1.93	-447.57
2280.80	10477.30	1786.19	-1329.25	-592.78	1964.97	1.97	1.96	-522.77
137.42	12222.00	1597.60	-934.20	195.16	1966.81	1.98	1.80	-516.98
131.09	8830.61	1421.38	-1556.70	-555.26	1962.51	2.01	1.83	-430.22
12917.80	8622.10	3053.53	-1757.47	-517.74	1965.58	2.02	1.83	-476.49
8172.98	10527.50	2731.52	-1432.65	-105.01	1962.51	2.04	1.88	-522.77
8674.13	9708.59	2602.27	-1441.39	-187.56	1966.20	2.05	1.89	-474.57
9414.08	10275.10	2573.17	-1380.05	60.08	1962.51	2.09	1.91	-453.36
8637.82	10109.30	2315.95	-1429.79	-367.66	1966.81	2.11	1.92	-430.22
6078.28	9987.05	2391.31	-1480.58	-427.69	1962.51	2.06	1.96	-420.58
4411.12	9521.44	2422.42	-1566.65	-397.67	1966.81	1.96	1.96	-505.41
6112.30	9389.17	2179.80	-1423.01	-22.46	1963.12	1.98	1.82	-501.56
5494.13	9309.17	2093.32	-1423.01	-67.49	1964.97	2.01	1.83	-439.86
5666.16	9997.49	2333.66	-1492.94	-44.98	1964.35	2.01	1.85	-491.92
4460.58	8656.01	2524.57	-1816.40	-450.20	1964.97	2.06	1.88	-507.34
4151.34	7962.67	2086.14	-1866.45	-442.70	1965.58	2.04	1.89	-491.92
3659.20	9800.29	2089.39	-1423.76	90.10	1966.81	2.09	1.92	-474.57
2807.07	8205.09	1834.90	-1724.61	-427.69	1967.43	2.09	1.92	-445.64
3764.26	8075.71	1942.99	-1773.30	-480.22	1968.04	2.13	1.96	-439.86
-296.95	6334.81	1586.67	-2078.37	-510.24	1966.81	1.96	1.96	-468.78
-3986.51	5680.40	1059.84	-2067.37	-540.25	1967.43	1.98	1.82	-507.34
-3625.93	8085.76	1044.42	-1533.34	-517.74	1966.81	1.98	1.83	-503.49
-4862.97	8781.62	881.16	-1423.31	-480.22	1966.81	2.02	1.87	-466.85
-3065.43	8544.22	1408.53	-1445.16	-472.72	1967.43	2.04	1.87	-474.57
-3114.89	3084.12	1386.38	-2382.24	-562.77	1965.58	2.05	1.92	-476.49
-664.55	8112.14	1435.56	-1337.84	-525.25	1966.81	2.07	1.91	-457.21
-1948.88	6641.29	1404.53	-1709.99	-525.25	1964.97	2.11	1.94	-426.36
-4085.33	9202.40	1119.00	-1366.18	-457.71	1967.43	2.12	1.96	-507.34
-2572.00	8402.29	1122.44	-1359.40	-495.23	1964.35	1.96	1.86	-524.70
-3453.90	3324.03	1284.76	-2300.39	-555.26	1961.28	1.98	1.82	-449.50
454.97	8050.59	1919.70	-1504.40	-457.71	1961.89	1.99	1.84	-505.41
-1622.33	10135.70	1600.62	-1234.29	-457.71	1958.82	2.01	1.87	-491.92
-3279.20	8305.57	1222.87	-1497.01	-480.22	1958.82	2.04	1.89	-466.85
-2398.09	5877.60	806.79	-1702.15	-630.31	1962.51	2.05	1.89	-468.78
-4403.57	7053.28	806.58	-1428.43	-600.29	1959.43	2.08	1.93	-461.07
-4079.59	8813.02	1568.37	-1542.23	-487.73	1963.12	2.11	1.94	-474.57
-5499.45	5475.66	256.33	-1743.75	-592.78	1960.05	2.11	1.98	-507.34
-2614.64	6812.11	659.90	-1105.87	-637.81	1958.82	1.96	1.82	-507.34
-715.40	4729.56	1352.80	-1750.39	-585.28	1958.82	1.96	1.82	-455.29
-1300.14	9282.79	1327.96	-1184.10	-450.20	1957.59	2.00	1.86	-489.99
407.58	11091.50	1788.47	-996.90	-202.57	1961.28	2.01	1.87	-518.91
2064.46	9498.83	2166.22	-1237.76	-315.13	1958.20	2.05	1.89	-503.49
2053.97	8767.80	2048.17	-1318.85	-135.03	1961.28	2.06	1.91	-497.70
2777.20	7413.77	1988.25	-1507.86	-330.14	1958.82	2.06	1.94	-476.49
2063.66	8233.98	1912.46	-1469.13	-525.25	1958.82	2.11	1.96	-480.35
191.04	7703.92	1641.59	-1529.42	-532.75	1959.43	2.07	1.82	-515.05
24.65	8053.10	1587.16	-1444.41	-397.67	1954.51	1.96	1.82	-530.48

-1344.06	3606.64	1140.26	-2067.52	-562.77	1954.51	1.98	1.85	-472.64
540.43	4139.21	1517.81	-1947.24	-607.79	1956.36	2.00	1.86	-449.50
271.56	4341.44	1044.08	-1896.44	-622.80	1953.90	2.04	1.88	-484.21
-2270.30	5520.42	903.75	-1787.16	-637.81	1956.36	2.04	1.91	-507.34
-3402.56	3913.12	830.92	-2133.53	-802.90	1955.74	2.05	1.92	-488.06
-1739.46	7323.33	1121.43	-1495.51	-555.26	1955.74	2.09	1.96	-497.70
319.14	5818.57	1702.23	-1808.72	-532.75	1957.59	2.09	1.80	-482.28
-430.32	5105.13	1446.74	-1904.28	-585.28	1953.90	2.02	1.83	-484.21
-1721.15	7261.78	1659.78	-1662.06	-547.76	1955.74	1.96	1.83	-509.27
2123.61	5868.81	2132.67	-1912.12	-690.34	1953.90	1.97	1.85	-501.56
807.13	7058.30	1757.15	-1742.85	-540.25	1956.36	2.01	1.89	-495.77
113.58	5509.58	1136.80	-1802.69	-600.29	1957.59	2.02	1.89	-518.91
-11.07	6175.29	1027.69	-1543.74	-532.75	1956.36	2.05	1.93	-530.48
-358.29	4632.85	1385.85	-1888.00	-675.33	1958.82	2.07	1.94	-501.56
-1512.22	6962.04	1913.29	-1850.47	-585.28	1953.90	2.09	1.82	-486.13
-235.82	9463.66	1260.58	-1208.82	-480.22	1956.97	2.11	1.82	-472.64
-1770.02	8149.82	1284.47	-1306.79	-532.75	1956.97	2.01	1.84	-468.78
1818.63	9242.59	1899.54	-1275.14	-585.28	1955.13	1.96	1.87	-501.56
2310.77	10305.20	1896.30	-1094.57	-555.26	1957.59	1.99	1.87	-491.92
1574.19	5817.31	1613.47	-1838.71	-502.73	1956.97	2.02	1.91	-480.35
-2811.59	5037.30	768.52	-1786.41	-765.38	1960.05	2.03	1.91	-463.00
-2273.35	6226.79	1179.35	-1617.14	-540.25	1960.05	2.05	1.96	-503.49
-134.72	7322.08	1699.26	-1525.50	-555.26	1962.51	2.05	1.80	-497.70
4800.18	8492.73	2273.04	-1371.76	-555.26	1959.43	2.08	1.82	-437.93
5610.47	9608.11	2318.75	-1234.60	-525.25	1963.12	2.09	1.84	-468.78
6084.51	8584.42	2304.07	-1354.12	-442.70	1960.05	2.13	1.87	-478.42
4582.26	7744.11	2145.54	-1438.38	-540.25	1962.51	1.96	1.87	-493.05
2768.09	7941.31	1850.80	-1507.56	-547.76	1961.28	1.99	1.89	-518.91
4864.09	9616.90	1908.17	-1024.63	-457.71	1964.35	2.01	1.91	-480.35
4300.22	8427.41	1855.99	-1193.90	-540.25	1961.89	2.02	1.94	-484.21
1931.30	5434.21	1646.52	-1864.79	-517.74	1963.74	2.04	1.98	-484.21
1572.11	9791.49	1642.55	-1199.33	-562.77	1963.12	2.04	1.82	-526.62
4035.01	8956.21	1860.72	-1163.60	-495.23	1961.89	2.08	1.84	-474.57
2516.04	8115.91	1671.36	-1247.86	-547.76	1964.35	2.09	1.85	-407.08
850.26	8657.27	1683.08	-1352.01	-472.72	1961.28	2.04	1.89	-499.63
-945.69	6472.98	1663.24	-1819.72	-592.78	1963.74	1.96	1.80	-522.77
-565.63	6074.81	1639.87	-1771.34	-547.76	1960.05	1.99	1.91	-503.49
-885.95	6749.31	1356.53	-1736.82	-742.87	1962.51	2.01	1.94	-457.21
600.18	6790.76	1211.10	-1615.79	-577.78	1962.51	2.02	1.80	-495.77
-2032.37	8231.46	1513.89	-1529.12	-630.31	1961.89	2.04	1.82	-507.34
-2483.36	5195.56	1735.60	-2351.03	-1268.16	1963.74	2.05	1.83	-507.34
-1487.40	7921.22	1300.87	-1553.08	-502.73	1960.05	2.08	1.87	-472.64
-361.06	10712.20	1424.62	-932.99	-540.25	1963.12	2.10	1.87	-464.93
733.44	9443.57	1994.26	-1254.34	-607.79	1959.43	1.94	1.87	-482.28
-182.59	8002.06	2104.64	-1775.41	-532.75	1960.05	1.98	1.92	-538.19
2249.64	6758.10	2222.39	-1961.25	-532.75	1960.05	1.99	1.92	-516.98
4301.12	8818.05	2373.21	-1422.25	-472.72	1955.74	2.02	1.80	-507.34
-1094.08	5706.78	1356.79	-1871.87	-1155.60	1957.59	2.02	1.82	-445.64
6964.54	9567.92	2697.75	-1325.64	-562.77	1958.20	2.03	1.83	-486.13
3664.94	7541.09	2530.76	-1923.57	-592.78	1957.59	2.07	1.87	-480.35
2006.58	6573.46	1916.93	-2026.52	-607.79	1960.05	2.09	1.87	-464.93
1492.18	9692.27	1966.90	-1396.93	-562.77	1958.82	2.13	1.91	-461.07
3920.36	9914.59	2406.20	-1300.61	-487.73	1959.43	1.94	1.91	-468.78
2004.61	7752.90	2209.47	-1662.81	-532.75	1958.20	1.98	1.94	-518.91
6712.40	9570.43	2510.31	-1265.65	-405.10	1958.82	2.00	1.96	-499.63
7304.27	9861.83	2640.78	-1257.21	-487.73	1957.59	2.02	1.82	-436.00
4230.78	9733.72	2298.40	-1275.90	-315.13	1957.59	2.04	1.83	-488.06
1192.04	7170.09	1665.92	-1679.69	-540.25	1960.05	2.04	1.85	-518.91
6470.42	6774.43	2086.04	-1571.32	-457.71	1961.89	2.07	1.89	-491.92
4186.76	6925.16	1855.25	-1881.52	-592.78	1963.12	2.09	1.88	-455.29
-1682.97	10248.70	1390.10	-1141.14	-532.75	1962.51	2.13	1.92	-484.21
675.77	8320.65	2271.89	-1571.47	-592.78	1961.89	1.96	1.92	-495.77
2016.28	6570.95	1781.23	-1652.11	-547.76	1958.82	2.00	1.96	-455.29
-750.12	10118.10	1574.01	-1219.82	-345.15	1960.05	2.00	1.80	-516.98
3419.01	8549.25	2008.62	-1325.18	-277.61	1958.82	2.01	1.83	-472.64
1572.90	7343.43	1896.32	-1449.99	-390.17	1960.05	2.04	1.85	-468.78
-534.27	5358.85	1730.58	-1926.89	-525.25	1961.89	2.04	1.87	-499.63
1668.86	8735.15	1612.47	-1229.92	-90.00	1961.28	2.09	1.89	-499.63
5452.39	8826.84	2148.00	-1212.29	-322.63	1963.12	2.11	1.91	-445.64
4082.39	8370.89	1991.95	-1240.47	-277.61	1961.28	2.00	1.94	-461.07
2557.88	8554.27	1800.14	-1205.20	172.65	1960.05	1.96	1.95	-526.62
3732.90	7967.69	1852.27	-1312.07	-195.06	1958.82	1.98	1.80	-547.83
1929.71	8638.43	1138.99	-933.14	-345.15	1958.82	2.01	1.82	-451.43
8404.56	9398.35	2138.24	-1030.96	-502.73	1960.05	2.01	1.83	-463.00
3684.02	11375.40	1476.97	-734.03	-532.75	1960.05	2.04	1.88	-518.91
3766.92	9746.28	1640.76	-975.95	-487.73	1963.12	2.06	1.89	-516.98
2440.75	7889.82	1400.95	-1434.16	-555.26	1958.82	2.09	1.91	-511.20
5640.24	8564.32	1901.94	-1399.64	-525.25	1958.20	2.11	1.94	-476.49
3957.85	9145.88	2146.30	-1412.76	-517.74	1958.82	1.94	1.94	-489.99
6154.64	7696.38	1851.97	-1709.39	-675.33	1953.90	1.96	1.80	-503.49
8223.63	8762.78	2287.37	-1438.83	-540.25	1954.51	1.98	1.82	-524.70
6117.25	8230.21	2375.41	-1559.11	-517.74	1954.51	2.01	1.83	-513.13
-341.47	5530.93	1680.13	-2161.57	-847.93	1952.05	2.01	1.88	-503.49
-3726.73	5930.36	1396.12	-2179.96	-1335.70	1952.05	2.05	1.89	-520.84
-4500.21	6684.00	1100.12	-1993.36	-1478.28	1953.90	2.07	1.91	-486.13
-7507.49	6303.41	821.82	-1959.44	-1891.01	1950.82	2.09	1.92	-480.35
-403.98	6818.39	2025.60	-1824.69	-1245.65	1950.82	1.93	1.78	-489.99
-7290.64	4679.32	1759.07	-2515.78	-1358.21	1952.05	1.96	1.80	-518.91

-4656.02	6516.94	1427.21	-2073.09	-630.31	1948.98	1.98	1.83	-542.05
-1792.87	6964.10	1604.35	-1820.47	-682.83	1950.82	2.01	1.85	-513.13
172.34	7081.02	1903.31	-1644.12	-577.78	1952.67	2.01	1.87	-451.43
3964.98	9527.72	2576.28	-1416.67	-555.26	1951.44	2.05	1.91	-491.92
-44.79	6019.54	2029.57	-2222.31	-1260.66	1952.67	2.06	1.91	-466.85
3503.99	6999.27	2143.32	-1849.41	-690.34	1952.05	2.10	1.95	-464.93
3446.32	7160.04	2420.95	-1919.65	-847.93	1953.28	2.04	1.80	-466.85
1573.59	7289.42	1886.62	-1870.97	-765.30	1952.67	1.93	1.80	-464.93
4689.59	7948.85	2496.98	-1761.99	-862.94	1953.90	1.97	1.83	-509.27
3142.13	5601.27	2441.59	-2219.45	-1193.12	1955.74	1.98	1.84	-503.49
-2545.28	5944.17	1807.93	-2284.41	-1193.12	1955.13	2.02	1.88	-515.05
3618.94	6064.76	2300.14	-2011.29	-697.84	1958.82	2.02	1.89	-476.49
4222.68	6569.69	2941.63	-2116.50	-892.95	1957.59	2.06	1.92	-507.34
2182.77	5694.22	2099.11	-2171.82	-952.99	1959.43	2.07	1.94	-491.92
516.89	5090.05	1847.38	-2264.22	-1193.12	1958.82	2.11	1.97	-474.57
-143.62	4975.75	2088.73	-2387.36	-1320.69	1960.05	2.04	1.82	-472.64
1921.71	7049.51	2045.68	-1952.81	-660.32	1957.59	1.96	1.83	-486.13
260.78	7893.58	1989.55	-1778.57	-562.77	1958.82	1.98	1.85	-507.34
2812.61	10375.60	1757.35	-1152.45	-577.78	1958.82	1.98	1.87	-495.77
5406.39	7958.90	1997.39	-1522.03	-1208.13	1960.05	2.04	1.89	-468.78
-2565.56	5106.38	1562.12	-2308.68	-1455.77	1962.51	2.02	1.91	-515.05
-7121.69	4865.22	1247.81	-2420.52	-1688.40	1958.82	2.07	1.94	-553.62
-3469.23	8573.11	1234.56	-1624.08	-952.99	1958.82	2.10	1.96	-505.41
-2393.94	9919.61	748.63	-1180.64	-1178.11	1957.59	2.09	1.80	-468.78
-1794.36	7751.65	1360.28	-1692.81	-1380.72	1953.28	1.94	1.83	-464.93
-6289.25	5970.55	983.34	-2088.92	-2213.69	1955.13	1.96	1.84	-449.50
-5221.47	8722.58	867.50	-1529.87	-1448.26	1955.13	1.98	1.84	-545.90
-2632.74	10963.40	648.47	-1015.59	-1410.74	1951.44	2.02	1.89	-495.77
-182.90	9241.34	1314.26	-1305.14	-1260.66	1952.05	2.02	1.92	-478.42
-2684.57	6886.22	1638.92	-1942.56	-1013.02	1952.67	2.04	1.94	-520.84
-4094.33	8002.86	1245.01	-1775.41	-1140.59	1948.36	2.05	1.78	-559.40
-1156.80	10278.80	1175.35	-1290.06	-1125.58	1947.75	2.09	1.82	-484.21
-4807.38	8853.22	632.61	-1451.19	-1110.57	1947.75	1.92	1.83	-507.34
-3730.39	10665.70	917.67	-1174.00	-870.44	1947.75	1.95	1.83	-536.26
-4398.03	9915.84	729.04	-1270.62	-1073.05	1945.90	1.99	1.87	-520.84
-3699.03	8924.81	1008.39	-1479.08	-1058.04	1945.90	2.01	1.91	-545.90
-2342.89	7933.78	1358.31	-1687.53	-1088.06	1947.75	2.01	1.92	-542.05
-2246.14	11473.40	1328.23	-1000.82	-622.80	1943.44	2.04	1.78	-488.06
-6855.19	6135.10	960.24	-2069.17	-998.01	1945.29	2.06	1.81	-542.05
-2363.86	8726.35	1122.19	-1439.89	-697.84	1946.52	2.07	1.82	-491.92
-3967.81	10238.70	798.12	-946.71	-562.77	1943.44	1.90	1.87	-518.91
-5000.28	8879.59	419.61	-1255.70	-607.79	1944.67	1.96	1.87	-524.70
-2680.13	8769.06	517.24	-1288.86	-877.94	1946.52	1.97	1.88	-549.76
-744.78	9228.78	969.55	-1170.69	-727.86	1943.44	2.00	1.91	-538.19
-739.25	9912.08	892.00	-926.21	-660.32	1944.67	2.02	1.91	-505.41
-3410.38	12548.60	410.63	-520.30	-517.74	1945.90	2.02	1.79	-472.64
-3012.11	12735.70	662.15	-395.04	-547.76	1943.44	2.04	1.82	-522.77
-755.07	11321.40	1378.40	-720.62	-360.15	1945.90	2.08	1.85	-574.82
681.00	11409.30	1403.97	-792.96	-187.56	1946.52	2.10	1.87	-499.63
-556.04	8605.77	1240.70	-1278.61	-487.73	1944.67	1.95	1.87	-426.36
-66.07	8315.62	1003.08	-1257.05	-540.25	1947.13	1.96	1.89	-495.77
-3596.85	8308.08	637.31	-1437.02	-1140.59	1947.75	2.00	1.92	-522.77
1547.67	10527.50	1454.90	-998.26	-562.77	1948.98	2.02	1.94	-507.34
510.46	10640.60	1407.70	-905.11	-540.25	1950.82	2.01	1.79	-530.48
4350.97	9320.47	1675.30	-1153.05	-532.75	1948.98	2.04	1.82	-461.07
20.98	9792.75	1108.71	-1169.33	-532.75	1951.44	2.07	1.84	-509.27
-697.99	9240.08	1373.93	-1335.13	-562.77	1949.59	2.09	1.87	-576.75
3753.08	10693.30	1034.63	-940.52	-367.66	1950.21	1.94	1.87	-499.63
4602.44	9719.90	2127.89	-1171.44	-532.75	1952.67	1.96	1.89	-464.93
4953.12	10049.00	1721.26	-1131.95	-577.78	1948.98	1.99	1.92	-505.41
3458.58	11297.50	1719.56	-856.12	-502.73	1952.05	2.00	1.94	-553.62
1187.10	9902.03	1470.32	-1166.17	-532.75	1951.44	2.00	1.79	-534.34
-791.38	8431.18	1092.08	-1538.31	-525.25	1948.98	2.04	1.83	-567.11
3775.23	9135.83	1524.44	-1218.32	-495.23	1947.75	2.06	1.85	-509.27
3136.98	9757.58	1719.07	-1140.39	-555.26	1949.59	2.09	1.86	-542.05
4266.68	9461.15	1530.89	-1268.81	-487.73	1945.90	1.91	1.87	-530.48
4911.47	10466.00	2039.40	-1164.81	-502.73	1944.06	1.96	1.91	-493.85
5795.55	9292.84	2111.46	-1378.54	-547.76	1945.29	1.96	1.75	-470.71
1512.95	10483.60	1676.11	-1179.28	-547.76	1944.67	1.98	1.77	-538.19
4507.77	10413.20	2128.89	-1121.40	-345.15	1944.67	2.01	1.82	-559.40
11236.40	10001.30	2488.13	-968.56	-195.06	1945.29	2.04	1.85	-447.57
11329.00	9164.72	2516.21	-1397.23	-540.25	1946.52	2.05	1.85	-476.49
9080.50	9238.83	2210.55	-1365.13	-472.72	1947.13	2.09	1.89	-520.84
5944.53	9933.43	2144.76	-1285.09	-547.76	1950.21	1.91	1.89	-499.63
430.33	11229.70	1205.14	-738.25	-120.02	1945.90	1.95	1.76	-476.49
5358.41	11316.40	2139.31	-840.59	-232.58	1948.98	1.96	1.78	-464.93
6297.49	12631.50	2235.97	-712.63	0.05	1947.75	1.98	1.80	-489.99
3584.12	10154.50	2345.89	-1218.77	-82.50	1948.98	2.01	1.83	-505.41
940.40	8943.65	1633.62	-1463.55	-7.46	1952.05	2.01	1.85	-463.00
2208.39	9311.68	1740.46	-1363.02	-367.66	1951.44	2.07	1.88	-461.07
37.11	9678.45	1412.68	-1292.48	-322.63	1955.74	2.08	1.90	-459.14
4699.67	8801.72	1561.21	-1377.79	-547.76	1952.67	2.11	1.93	-497.70
8439.48	7918.71	2443.95	-1613.07	-517.74	1956.97	1.93	1.85	-507.34
6234.18	9531.49	2327.68	-1326.69	-255.09	1952.05	1.96	1.80	-480.35
10243.20	9384.53	2620.63	-1360.91	-457.71	1955.13	1.98	1.82	-461.07
1490.10	10026.40	1995.98	-1237.46	-397.67	1954.51	2.00	1.83	-495.77
1458.05	9493.81	1914.96	-1357.74	-525.25	1953.28	2.03	1.87	-476.49
5591.67	9020.27	2317.01	-1371.44	-420.19	1954.97	2.04	1.88	-501.54

[illegible]	[illegible]	[illegible]	-1680.80	-525.25	1953.90	2.06	1.91	-447.57
512.44	10664.50	1115.16	-1204.00	-547.76	1955.13	2.10	1.94	-499.63
972.14	9714.88	1830.96	-1291.42	-487.73	1955.74	2.00	1.79	-513.13
1681.32	10499.90	1438.00	-1223.74	-487.73	1952.05	1.95	1.80	-491.92
12957.30	11678.10	2764.47	-890.03	-442.70	1952.67	1.96	1.82	-432.15
235.55	11469.60	1548.13	-1090.80	-525.25	1952.67	1.98	1.83	-434.08
12808.50	9198.63	2933.73	-1456.17	-465.21	1953.90	2.02	1.87	-526.62
8064.16	8918.53	2136.01	-1629.05	-457.71	1957.59	2.02	1.88	-522.77
6776.18	10305.20	1626.53	-1094.57	-525.25	1953.90	2.06	1.92	-472.64
5069.84	9939.71	1146.62	-1135.12	-525.25	1955.74	2.09	1.87	-497.70
4529.03	10486.10	1301.48	-1119.29	-510.24	1953.90	2.09	1.79	-515.05
-1401.24	8554.27	809.28	-1639.60	-667.83	1952.05	1.94	1.82	-520.84
37.50	11501.00	612.62	-775.33	-465.21	1954.51	1.96	1.83	-478.42
-1966.69	10859.10	329.57	-898.78	-517.74	1951.44	1.98	1.84	-451.43
-3709.72	11679.40	363.41	-860.04	-577.78	1952.67	2.01	1.87	-511.20
-3316.79	8540.46	1219.39	-1535.15	-960.49	1953.90	2.01	1.91	-549.76
-4132.82	9251.39	724.31	-1499.57	-585.28	1950.21	2.05	1.94	-491.92
-2498.51	13508.20	358.41	-192.92	-577.78	1948.98	2.07	1.79	-437.93
279.17	12645.30	937.46	-382.68	-517.74	1952.05	2.09	1.80	-472.64
2447.58	11130.50	1040.56	-935.85	-547.76	1948.98	1.93	1.84	-503.49
1984.12	11663.00	1436.75	-815.57	-495.23	1950.21	1.95	1.85	-495.77
3207.80	10854.10	1257.27	-1018.75	-570.27	1952.05	1.97	1.85	-476.49
-1585.94	10983.50	296.51	-970.07	-1275.67	1948.98	2.01	1.89	-430.22
-286.97	13572.20	387.44	-400.77	-570.27	1952.05	2.02	1.91	-437.93
-2135.16	13191.70	304.22	-366.86	-570.27	1952.05	2.03	1.93	-538.19
-1311.52	12915.30	692.68	-449.76	-532.75	1952.05	2.05	1.80	-507.34
216.55	12657.80	1019.48	-517.13	-495.23	1953.90	2.07	1.81	-443.72
1915.66	12222.00	805.94	-499.80	-570.27	1952.67	2.11	1.84	-463.00
-708.12	10751.10	516.70	-871.95	-532.75	1953.90	1.93	1.85	-499.63
2323.62	9429.75	921.75	-1149.89	-660.32	1953.28	1.98	1.87	-451.43
-223.46	9317.96	822.64	-1213.04	-652.82	1956.36	1.99	1.89	-443.72
-2044.44	7867.21	808.30	-1539.67	-787.89	1953.90	2.01	1.91	-474.57
-5472.24	8526.64	405.21	-1430.69	-915.46	1956.36	2.05	1.80	-491.92
-4703.71	10817.70	505.60	-1019.81	-532.75	1956.97	2.02	1.79	-507.34
-1176.19	7423.82	1446.76	-1702.30	-1193.12	1955.13	2.06	1.83	-441.79
-2033.95	8958.72	1006.36	-1538.01	-832.92	1956.36	2.07	1.85	-437.93
-5699.87	10943.30	413.42	-1061.11	-525.25	1955.74	2.12	1.87	-464.93
-5732.61	7847.11	342.08	-1585.19	-1020.52	1956.97	1.94	1.87	-404.21
-4712.81	8654.76	368.16	-1412.00	-1275.67	1956.36	1.97	1.90	-459.14
-1289.26	10963.40	645.95	-1015.59	-780.39	1957.59	2.01	1.82	-401.30
-476.21	13852.30	652.89	-227.89	-495.23	1957.59	2.00	1.77	-497.70
1175.82	11507.30	1098.50	-625.36	-577.78	1956.36	2.04	1.82	-538.19
-3796.09	8478.91	248.09	-1267.30	-877.94	1957.59	2.04	1.83	-463.00
-2802.10	11272.40	105.90	-587.22	-555.26	1956.36	2.07	1.87	-463.00
-4659.39	10994.80	-114.77	-700.12	-525.25	1957.59	2.09	1.89	-528.55
-5015.82	10703.40	-157.51	-708.56	-585.28	1958.82	2.11	1.91	-532.41
-5997.33	11311.30	-109.80	-526.18	-637.81	1949.59	1.95	1.76	-524.70
-5223.26	12709.30	-166.95	-156.14	-187.56	1952.67	1.97	1.78	-491.92
-4907.20	14136.20	-80.91	34.98	-360.15	1952.67	1.98	1.80	-464.93
-3207.30	11970.80	-48.69	-417.20	-487.73	1950.21	2.00	1.82	-464.93
-4346.20	12495.80	-261.42	-476.89	-510.24	1952.05	2.05	1.85	-538.19
-4871.78	12744.50	-319.81	-185.08	-427.69	1953.90	2.05	1.87	-468.78
-4487.46	14009.40	-137.89	46.29	-82.50	1951.44	2.08	1.91	-478.42
-2602.97	13967.90	231.66	-74.75	-210.07	1951.44	2.10	1.78	-486.13
-717.78	13763.20	591.51	-185.53	-232.58	1951.44	1.83	1.78	-515.05
-2401.07	12483.20	318.64	-342.44	-435.20	1949.59	1.96	1.81	-424.44
-3471.12	11055.10	-63.35	-563.56	-540.25	1953.90	1.97	1.82	-407.08
-5718.27	10316.50	-388.39	-824.62	-502.73	1952.05	2.01	1.85	-426.36
-1926.43	10574.00	30.82	-757.24	-547.76	1956.97	2.02	1.87	-451.43
-1013.07	13764.40	222.67	-155.54	-427.69	1956.36	2.04	1.91	-540.12
-13.45	13250.70	266.40	-260.29	240.18	1958.82	2.06	1.93	-470.71
-1335.47	11808.70	-31.58	-376.96	-330.14	1957.59	2.07	1.79	-424.44
-242.36	12685.50	557.45	-291.65	142.63	1959.43	2.09	1.80	-505.41
1886.48	12039.80	949.60	-505.08	-337.64	1958.82	2.13	1.83	-503.49
-818.78	12478.20	416.29	-462.42	-367.66	1960.05	1.96	1.84	-449.50
1290.56	8650.99	816.39	-1067.59	-547.76	1959.43	1.98	1.87	-364.67
2474.29	7038.21	1726.04	-1788.37	-1515.80	1962.51	2.01	1.87	-422.51
5799.01	11532.40	2062.99	-894.25	-517.74	1961.28	2.04	1.91	-501.56
4733.90	9866.86	1876.61	-1137.23	-307.62	1964.35	2.05	1.92	-455.29
1069.97	11395.50	991.13	-688.51	-82.50	1960.05	2.05	1.79	-459.14
4395.48	10699.60	1581.84	-798.54	-480.22	1966.20	2.07	1.80	-457.21
5801.29	6000.70	2106.26	-2237.84	-2003.57	1963.12	2.10	1.84	-445.64
-5023.62	4774.78	1276.10	-2408.16	-2686.46	1966.20	2.11	1.85	-428.29
-1380.96	9111.96	1135.09	-1353.82	-772.88	1963.74	1.96	1.87	-447.57
6041.28	10487.40	2114.68	-1089.29	-532.75	1965.58	2.00	1.91	-472.64
10638.60	9359.41	2647.46	-1526.40	-1245.65	1965.58	2.00	1.91	-378.16
8497.95	8443.74	2420.09	-1672.76	-1035.53	1962.51	2.02	1.78	-434.08
11804.00	10169.60	2957.86	-1293.23	-592.78	1965.58	2.02	1.80	-443.72
8866.14	12747.00	2298.05	-559.49	-435.20	1961.89	2.05	1.83	-426.36
9808.78	11954.40	2609.70	-807.13	-435.20	1964.35	2.07	1.85	-447.57
11802.60	10389.40	3038.14	-1256.90	-562.77	1962.51	2.11	1.87	-441.79
6539.65	6578.49	2024.20	-1906.54	-570.27	1964.97	2.09	1.91	-501.56
-2808.85	6586.02	790.64	-1726.57	-2026.09	1963.12	1.96	1.91	-466.85
-4702.22	4405.50	749.67	-2104.29	-3669.51	1961.28	1.98	1.76	-414.80
-3432.54	4838.84	720.81	-1747.22	-4007.20	1961.89	2.00	1.79	-339.60
-2281.86	8071.94	768.76	-994.49	-2949.10	1956.97	2.02	1.82	-399.37
-2574.77	7652.42	1161.21	-1021.62	-2453.83	1960.66	2.04	1.85	-457.21
-3656.39	9673.42	1470.93	-978.06	-1778.45	1961.28	2.06	1.87	-407.08

-2041.37	11533.70	1639.90	-864.26	-525.25	1958.82	2.09	1.91	-434.08
7264.57	10520.00	2735.27	-743.83	7.55	1958.82	2.11	1.92	-489.99
7927.95	9432.26	2718.60	-1089.90	382.76	1956.36	1.93	1.76	-507.34
11021.00	9992.46	3385.38	-1178.53	555.36	1955.74	1.96	1.80	-424.44
10765.40	4193.22	2990.94	-1960.65	37.57	1958.82	1.98	1.81	-387.80
15280.00	6275.78	3886.85	-1750.54	277.70	1956.97	2.01	1.85	-434.08
13542.40	4978.26	3579.68	-1892.97	262.70	1960.05	2.04	1.85	-439.86
12968.00	4944.35	3409.44	-1834.04	375.26	1958.20	2.05	1.90	-409.01
12784.80	4563.76	3060.74	-1800.13	435.29	1959.43	2.07	1.92	-410.94
9564.54	3668.65	2858.54	-2080.93	-427.69	1959.43	2.09	1.88	-364.67
12553.70	3596.59	3117.41	-1873.08	-97.51	1958.82	2.11	1.80	-428.29
9514.29	5974.32	2494.63	-1564.54	142.63	1958.82	1.93	1.80	-443.72
6137.92	6547.08	1821.15	-1353.22	-59.99	1959.43	1.98	1.83	-403.23
8789.57	6783.22	2310.47	-1361.36	-97.51	1961.89	2.00	1.84	-380.09
9266.58	6863.61	2783.94	-1613.68	292.71	1961.28	2.02	1.87	-434.08
7432.83	8092.04	2233.71	-1383.36	525.34	1963.12	2.03	1.89	-495.77
4101.09	6337.32	1730.23	-1583.98	225.18	1960.05	2.06	1.94	-439.86
8435.92	6018.28	2228.96	-1383.51	367.76	1961.89	2.09	1.81	-449.50
8367.07	7165.07	2398.22	-1365.28	82.59	1959.43	2.07	1.80	-422.51
7120.13	6602.35	1843.75	-1336.64	150.13	1958.82	2.11	1.83	-414.80
5423.59	6864.87	1491.60	-1149.28	-82.50	1960.05	1.94	1.84	-476.49
3572.64	6967.87	1447.15	-1296.09	-442.70	1955.74	1.98	1.87	-445.64
2540.27	9034.09	1332.10	-1041.51	-412.68	1959.43	2.01	1.89	-403.23
4135.71	9443.57	1245.57	-819.95	487.82	1956.97	2.02	1.91	-476.49
1083.71	9490.04	533.80	-578.93	450.30	1953.90	2.01	1.76	-464.93
-1992.61	10577.80	-102.15	-232.86	-165.04	1950.82	2.06	1.80	-399.37
104.37	10585.30	735.89	-487.29	-7.46	1952.05	2.07	1.82	-436.00
2364.78	11365.30	1140.22	-539.59	292.71	1952.05	2.09	1.83	-505.41
-1673.68	10623.00	200.57	-456.24	420.28	1948.98	2.01	1.87	-439.86
-3236.58	11159.30	-168.49	-245.97	285.21	1948.98	1.97	1.89	-397.44
6230.21	11171.90	1058.86	-380.42	-262.60	1949.59	1.98	1.91	-355.03
-2705.15	12331.30	602.74	-496.63	-37.47	1947.13	2.01	1.77	-383.95
-3335.40	10057.80	-109.33	-487.59	-97.51	1947.75	2.02	1.80	-409.01
-2634.43	10958.40	-122.52	-266.78	135.12	1949.59	2.02	1.82	-441.79
-2691.51	11833.90	-118.04	-211.46	277.70	1950.21	2.07	1.84	-432.15
-2693.48	13383.80	174.49	-121.62	255.19	1953.90	2.08	1.87	-484.21
-2512.56	12674.20	25.36	-127.20	757.97	1950.21	2.11	1.91	-515.05
-2991.54	11835.10	-155.57	-181.46	517.84	1952.05	2.13	1.92	-459.14
-3368.15	12548.60	-180.66	-85.90	307.72	1950.82	1.95	1.76	-470.71
-1649.94	12469.40	397.91	-237.99	-195.06	1950.21	1.98	1.79	-437.93
-3624.26	12343.80	-38.49	-196.69	52.58	1952.67	1.99	1.82	-437.93
-2821.00	12603.80	-159.30	-69.32	803.00	1948.98	2.01	1.84	-516.98
-2258.80	11435.70	69.10	-163.07	165.14	1952.05	2.06	1.86	-484.21
-1612.35	13019.60	401.39	-132.18	112.61	1952.67	2.05	1.88	-455.29
-540.42	12162.90	227.39	-171.97	150.13	1949.59	2.09	1.92	-447.57
-325.36	12292.30	130.20	-123.28	727.96	1950.21	2.11	1.95	-461.07
-1094.59	9935.94	39.50	-356.31	157.64	1952.05	2.11	1.78	-445.64
-744.99	11063.90	442.63	-353.59	7.55	1947.75	1.96	1.81	-428.29
-2393.35	11021.20	475.48	-504.62	105.11	1950.21	1.98	1.83	-463.00
-1414.80	10114.30	19.62	-441.02	135.12	1950.82	2.00	1.83	-443.72
-1600.68	10462.20	-26.85	-386.00	420.28	1949.59	2.04	1.87	-422.51
-2452.71	11359.10	-17.88	-255.17	525.34	1952.05	2.05	1.89	-463.00
-2537.48	12415.40	374.32	-224.57	142.63	1949.59	2.05	1.94	-463.00
-2172.75	12309.90	380.74	-137.75	645.41	1951.44	2.08	1.78	-480.35
-2937.83	11135.50	151.88	-381.48	37.57	1952.05	2.09	1.80	-453.36
-3009.55	10277.60	96.46	-451.27	-210.07	1949.59	2.13	1.83	-432.15
-3081.86	10803.90	314.19	-480.96	-352.65	1950.21	1.97	1.83	-397.44
-2462.89	11060.10	654.43	-443.58	120.12	1951.44	1.97	1.85	-445.64
-1163.33	12778.40	472.22	-244.02	495.33	1950.82	2.02	1.90	-441.79
-1649.35	12984.40	124.76	-103.24	938.07	1953.90	2.02	1.91	-472.64
-1975.90	12458.10	-71.33	-73.54	262.70	1949.59	2.04	1.77	-368.52
-2603.07	11686.90	-31.80	-245.67	-262.60	1953.28	2.05	1.80	-376.24
-1747.48	12416.70	174.22	-194.58	337.74	1952.05	2.07	1.83	-401.30
-1964.72	11887.90	37.03	-224.87	285.21	1956.36	2.11	1.85	-422.51
-1604.14	12729.40	21.61	-110.62	330.23	1955.74	2.13	1.87	-422.51
-586.32	13132.60	340.23	-39.03	255.19	1958.20	2.10	1.91	-407.08
3140.24	12445.60	1143.69	-373.49	240.18	1958.20	1.98	1.82	-403.23
641.62	13660.20	366.05	-38.72	757.97	1955.74	2.00	1.78	-420.58
-1081.23	13421.50	382.24	-90.57	532.85	1958.82	2.01	1.79	-428.29
829.09	14091.00	920.05	-176.04	352.75	1955.74	2.04	1.82	-372.38
-1349.90	11733.40	435.44	-439.06	-300.12	1958.82	2.05	1.83	-405.16
-2013.39	12542.30	188.65	-235.88	-7.46	1958.82	2.07	1.88	-383.95
-1402.24	11396.70	108.60	-224.12	-7.46	1961.89	2.09	1.91	-380.09
2128.74	12279.80	1001.29	-423.23	240.18	1960.05	2.11	1.76	-434.08
1345.67	11119.20	1104.46	-771.41	-202.57	1961.89	2.12	1.78	-420.58
-643.98	12204.40	617.85	-485.33	45.07	1961.28	2.06	1.82	-401.30
-258.28	12311.20	780.39	-542.15	-22.46	1961.89	1.99	1.82	-395.52
3453.53	13387.60	1260.49	-466.04	637.91	1961.89	2.00	1.83	-457.21
9578.88	12799.80	2120.07	-602.90	540.35	1962.51	2.04	1.87	-464.93
3368.76	8640.94	1652.70	-1307.55	112.61	1963.12	2.04	1.89	-430.22
-3315.02	10462.20	399.94	-820.40	127.62	1958.82	2.05	1.76	-445.64
1271.87	8560.55	1078.11	-1055.23	-292.62	1958.82	2.07	1.79	-434.08
2480.52	7926.24	1638.80	-1433.10	-420.19	1959.43	2.08	1.80	-403.23
-170.43	8222.67	1139.78	-1304.68	-502.73	1956.97	2.13	1.83	-399.37
-5439.50	9415.93	476.54	-1045.43	-322.63	1958.20	1.96	1.84	-403.23
126.93	11187.00	1479.54	-889.28	22.56	1956.36	1.97	1.87	-428.29
6301.64	11279.90	2177.81	-841.65	405.28	1955.74	2.01	1.89	-441.79
7195.52	11771.00	2377.62	-842.40	400.39	1954.51	2.01	1.75	-472.51

6245.16	11773.60	1909.13	-782.41	427.79	1952.67	2.03	1.78	-410.94
1874.91	10911.90	1641.30	-942.19	202.66	1953.90	2.05	1.82	-443.72
3535.94	10561.50	1960.89	-1057.19	75.09	1956.97	2.07	1.83	-428.29
3853.39	10997.30	2019.54	-1074.52	150.13	1953.90	2.11	1.87	-430.22
3936.08	8663.55	1656.42	-1202.04	-187.56	1955.13	2.12	1.90	-414.80
4806.31	9635.74	1922.34	-1009.11	135.12	1954.51	1.96	1.91	-432.15
3518.53	9189.84	1939.77	-1231.73	75.09	1952.67	1.98	1.76	-455.29
6782.02	9606.85	2339.35	-1264.59	37.57	1956.36	1.98	1.78	-441.79
2041.10	9199.89	1168.81	-991.77	-120.02	1953.90	2.02	1.82	-399.37
623.72	9331.78	881.53	-883.10	-14.96	1956.97	2.04	1.83	-420.58
3029.64	9035.34	1367.63	-1011.52	187.65	1955.13	2.05	1.87	-457.21
3048.54	9159.70	1632.82	-1082.81	-67.49	1956.36	2.08	1.89	-439.86
4736.57	9214.96	1574.38	-1066.23	-322.63	1958.20	2.09	1.91	-368.52
3243.22	8897.18	1026.37	-835.77	-82.50	1955.13	2.12	1.77	-376.24
2569.35	9409.65	924.98	-761.01	30.07	1957.59	1.95	1.78	-463.00
3915.11	9859.32	1420.30	-882.80	-240.09	1953.90	1.98	1.82	-436.00
4927.29	9620.67	1553.00	-934.65	-165.04	1956.97	2.01	1.83	-422.51
2753.15	9920.87	1000.53	-716.24	180.15	1956.97	2.02	1.84	-443.72
1492.37	10383.10	639.92	-538.08	-172.55	1956.36	2.04	1.90	-464.93
1839.79	11718.30	808.68	-364.60	-97.51	1957.59	2.06	1.78	-455.29
4703.24	12527.20	1776.20	-595.81	210.17	1953.90	2.06	1.76	-486.13
3878.90	10988.50	1397.43	-850.09	-150.04	1953.90	2.10	1.80	-443.72
-3268.33	10295.20	540.86	-900.13	-390.17	1953.90	2.02	1.82	-416.72
-2670.54	10066.60	118.07	-712.02	-532.75	1952.67	1.96	1.83	-463.00
-727.58	12499.60	463.76	-386.90	-472.72	1948.98	1.98	1.87	-480.35
-751.32	12592.50	266.41	-339.28	37.57	1950.21	2.02	1.91	-407.08
-2144.36	10791.30	-96.68	-346.51	705.44	1948.98	2.01	1.74	-461.07
-758.35	11928.10	99.89	-133.83	420.28	1945.90	2.04	1.78	-489.99
-2584.87	13035.90	243.09	-176.64	142.63	1945.90	2.06	1.81	-451.43
-1393.93	12637.70	-7.72	-128.26	277.70	1947.75	2.07	1.83	-422.51
-1975.20	12341.30	-81.03	-256.68	285.21	1947.13	2.10	1.83	-412.87
-2765.31	12401.60	-144.39	-120.12	-52.48	1945.29	1.96	1.87	-449.50
-2425.60	12553.60	-132.47	34.08	405.28	1947.13	1.96	1.89	-511.20
-2312.14	12693.00	-131.72	-111.68	97.60	1945.29	1.97	1.74	-443.72
-1863.12	12103.90	-60.90	-278.53	97.60	1942.21	2.01	1.78	-403.23
-2388.70	12176.80	-119.29	-276.42	307.72	1944.06	2.02	1.82	-491.92
-1843.64	12783.40	-68.85	-124.04	-367.66	1945.90	2.04	1.82	-461.07
-1901.41	13089.90	-54.68	-190.05	-285.11	1942.83	2.06	1.85	-445.64
-2390.09	13327.30	-99.91	-168.20	-37.47	1941.60	2.11	1.89	-470.71
-1315.98	13544.60	-39.53	-191.86	22.56	1939.14	1.94	1.82	-491.92
-2239.03	13396.40	-95.68	-256.07	-217.57	1938.52	1.95	1.75	-480.35
-2164.54	13823.50	-79.03	-48.97	52.58	1938.52	1.97	1.78	-470.71
-2126.95	14535.60	-75.55	16.59	675.43	1936.67	1.99	1.80	-493.85
-2106.77	14244.20	-93.20	8.15	803.00	1932.37	2.02	1.84	-532.41
-2410.96	14079.70	-72.57	-11.59	315.23	1932.98	2.05	1.87	-484.21
-2057.31	13842.30	8.95	-33.45	15.06	1932.37	2.07	1.91	-461.07
-408.05	14676.30	493.33	-99.17	585.38	1932.98	2.06	1.75	-495.77
-2316.29	14441.40	-73.56	-61.03	255.19	1931.14	1.92	1.76	-499.63
-852.91	14587.10	364.34	-56.81	953.08	1928.06	1.96	1.80	-549.76
-1895.56	13280.80	658.14	-409.21	150.13	1929.29	2.00	1.82	-491.92
-56.28	12747.00	1130.83	-559.49	-195.06	1931.75	2.02	1.83	-501.56
-666.24	12750.80	664.58	-469.50	52.58	1934.21	2.01	1.87	-497.70
-1943.84	11860.20	9.69	-450.36	-135.03	1930.52	2.04	1.73	-457.21
-264.61	12316.20	604.17	-422.18	-300.12	1932.98	2.07	1.76	-449.50
430.33	12126.50	1205.14	-607.42	-127.52	1935.44	2.02	1.79	-526.62
-2481.58	11129.20	916.15	-965.85	-517.74	1931.75	1.91	1.80	-516.98
-2274.34	11026.20	398.67	-819.04	-532.75	1930.52	1.97	1.82	-466.85
1030.61	12659.10	900.41	-487.14	-232.58	1932.37	1.99	1.85	-491.92
1351.31	12144.10	1290.37	-621.89	-525.25	1932.98	2.01	1.88	-524.70
-2060.47	9935.94	847.79	-1225.10	-532.75	1932.37	2.01	1.73	-476.49
-1654.79	9358.15	465.77	-1122.00	-540.25	1929.29	2.02	1.76	-484.21
-1446.65	10797.60	465.51	-630.93	-547.76	1929.91	2.07	1.80	-476.49
-2206.78	11801.20	512.26	-556.93	-495.23	1930.52	1.96	1.82	-495.77
-256.10	10314.00	1014.77	-884.61	-420.19	1930.52	1.93	1.83	-500.61
944.73	8819.30	1155.17	-1392.26	-540.25	1929.91	1.96	1.87	-488.06
2387.03	11620.30	1093.50	-532.21	-315.13	1927.45	1.98	1.83	-468.78
-1469.01	11057.60	248.78	-503.57	-405.18	1926.22	2.01	1.75	-493.85
115.55	11405.50	844.26	-448.55	-337.64	1929.29	2.02	1.79	-518.91
-184.48	12551.10	806.74	-460.31	-285.11	1930.52	2.04	1.81	-459.14
1921.20	12042.40	728.40	-445.09	-150.04	1929.29	2.07	1.83	-439.86
-2431.63	11490.90	481.69	-580.89	-427.69	1931.75	2.01	1.87	-447.57
-2316.09	10404.80	453.35	-714.89	-435.20	1932.98	1.93	1.87	-480.35
-1876.18	9037.86	386.73	-1385.93	-825.41	1930.52	1.95	1.72	-457.21
-2640.56	11388.00	228.18	-868.48	-517.74	1930.52	1.98	1.76	-424.44
-1945.03	12615.10	555.99	-233.77	37.57	1934.21	2.00	1.79	-501.56
-3289.89	11178.20	577.90	-664.85	-52.48	1934.83	2.00	1.82	-532.41
-1839.77	11194.50	936.51	-709.31	-442.70	1934.21	2.05	1.84	-474.57
374.05	8856.98	1463.38	-1361.21	-495.23	1936.06	2.08	1.87	-422.51
3376.37	10327.80	1546.07	-989.06	-510.24	1938.52	2.09	1.88	-451.43
3175.26	12345.10	1712.85	-601.09	-67.49	1935.44	1.94	1.92	-499.63
4226.42	11523.60	1829.64	-669.82	-67.49	1937.29	1.96	1.76	-499.63
6522.44	9717.39	2529.99	-1231.43	-172.55	1938.52	1.96	1.78	-518.91
2460.44	9056.70	1919.91	-1370.40	-187.56	1934.21	2.00	1.82	-449.50
111.60	8839.40	1429.33	-1346.74	-67.49	1937.90	2.02	1.85	-463.00
3612.51	9242.59	1948.46	-1275.14	142.63	1939.14	2.04	1.87	-480.35
5253.45	10134.40	2549.16	-1264.29	-135.03	1938.52	2.06	1.89	-436.00
9480.26	10243.70	2706.14	-1261.12	120.12	1938.52	2.10	1.92	-416.72
2164.56	8483.93	1824.22	-1581.72	-480.22	1940.98	2.00	1.77	-455.29

669.23	4674.30	1568.75	-2201.36	-532.75	1938.52	1.93	1.78	-430.22
-1698.30	6873.66	1339.90	-1808.11	-562.77	1939.75	1.97	1.82	-393.59
1495.64	9390.81	1918.44	-1210.93	-420.19	1943.44	2.00	1.83	-488.06
-2567.64	9090.61	1591.20	-1429.34	-397.67	1942.21	2.02	1.87	-453.36
-915.72	10100.50	1773.34	-1205.35	105.11	1946.52	2.02	1.89	-464.93
213.40	10557.70	1858.32	-1147.17	135.12	1945.29	2.05	1.91	-430.22
7772.15	11136.70	3045.69	-1220.28	210.17	1945.90	2.08	1.95	-426.36
6009.33	9237.57	2297.12	-1395.12	-105.01	1947.13	2.09	1.79	-407.08
2045.25	8554.27	1565.22	-1205.20	322.73	1945.90	1.95	1.82	-463.00
2781.04	7589.62	1393.48	-1218.17	7.55	1945.29	1.96	1.83	-518.91
2267.64	7083.42	1970.37	-1577.35	-592.78	1948.98	1.97	1.83	-422.51
5145.33	7859.67	1943.95	-1285.24	52.58	1944.06	2.01	1.87	-457.21
5830.27	8081.99	1890.25	-1188.93	315.23	1945.90	2.03	1.91	-491.92
7769.77	7804.40	2284.40	-1301.82	195.16	1947.13	2.03	1.93	-449.50
6218.15	7779.28	2287.17	-1467.32	-330.14	1944.06	2.05	1.79	-439.86
5177.97	9138.34	1751.83	-1158.33	52.58	1944.67	2.08	1.82	-430.22
5638.75	7935.03	1657.87	-1223.14	255.19	1947.13	2.11	1.83	-474.57
6864.02	8295.52	1985.92	-1302.57	547.86	1944.06	1.94	1.84	-532.41
6666.37	8107.11	2104.23	-1457.82	67.59	1943.44	1.98	1.87	-513.13
7617.23	7216.57	2036.11	-1438.68	7.55	1942.21	2.00	1.89	-464.93
4057.06	7296.95	1287.08	-1256.60	217.67	1941.60	2.01	1.91	-516.98
3762.57	8233.98	1172.01	-1034.73	75.09	1940.37	2.01	1.77	-476.49
6474.65	9539.03	1344.93	-712.33	7.55	1932.98	2.05	1.80	-410.94
3179.81	9996.23	854.63	-654.14	247.69	1938.52	2.07	1.83	-455.29
6825.33	10482.30	938.30	-340.48	457.81	1939.14	2.07	1.83	-457.21
7300.86	10221.10	1167.70	-497.04	165.14	1938.52	1.93	1.85	-461.07
4942.63	12075.00	1603.20	-534.01	375.26	1936.67	1.96	1.89	-470.71
13860.80	12252.10	2565.12	-648.72	232.68	1939.14	2.00	1.91	-459.14
8331.25	11341.50	1575.29	-675.10	247.69	1940.37	2.01	1.79	-455.29
-30.76	10321.60	508.73	-704.64	232.68	1939.14	2.02	1.80	-453.36
5392.93	12443.00	1391.18	-433.48	60.08	1941.60	2.03	1.82	-434.08
4027.09	11666.80	1176.97	-725.59	-390.17	1941.60	2.05	1.83	-420.58
-3558.77	13269.50	104.18	-244.77	52.58	1943.44	2.11	1.87	-449.50
-2469.32	13033.40	214.75	-236.63	67.59	1945.90	1.93	1.87	-476.49
9046.97	11263.60	1885.46	-797.19	97.60	1944.06	1.96	1.91	-536.26
8187.22	10968.40	1737.59	-895.61	-7.46	1944.06	1.98	1.94	-491.92
5497.19	11891.60	991.03	-569.29	52.58	1945.90	1.99	1.77	-476.49
6472.37	12174.20	847.10	-336.41	-97.51	1941.60	2.02	1.81	-470.71
5030.07	11841.40	908.77	-465.89	-262.60	1944.06	2.04	1.83	-468.78
7372.58	13797.10	1223.12	-244.47	37.57	1944.67	2.05	1.85	-476.49
-259.07	12971.80	526.63	-403.18	240.18	1943.44	2.08	1.87	-499.63
4769.70	12628.90	845.64	-338.22	532.85	1940.98	1.93	1.91	-520.84
8370.13	12302.40	1295.92	-317.72	30.07	1941.60	1.96	1.92	-507.34
-3680.54	13214.30	219.75	-261.35	142.63	1941.60	1.97	1.87	-489.99
-1922.67	11926.80	772.72	-598.22	-180.05	1938.52	1.98	1.78	-520.84
9305.05	12699.30	1450.75	-396.10	285.21	1936.06	2.01	1.82	-474.57
-1739.76	12608.80	331.06	-383.74	22.56	1936.67	2.03	1.85	-445.64
-2902.31	12904.00	184.44	-285.31	-232.58	1939.14	2.05	1.85	-463.00
-1420.14	12935.40	624.08	-404.24	-120.02	1938.52	2.08	1.88	-464.93
6854.72	12053.70	1321.56	-609.53	-157.54	1937.29	1.93	1.91	-530.48
-1555.86	12439.30	670.07	-523.46	-262.60	1937.29	1.96	1.93	-495.77
3976.93	11812.50	1084.51	-721.37	-307.62	1938.52	1.96	1.77	-489.99
608.39	12695.50	831.32	-486.08	-150.04	1934.83	1.98	1.80	-486.13
463.67	12101.40	1083.32	-772.92	-232.58	1934.83	2.01	1.84	-513.13
-1551.01	12598.80	602.21	-623.70	-7.46	1934.21	2.03	1.87	-507.34
8310.38	11298.80	1602.63	-826.12	-442.70	1936.67	2.06	1.87	-480.35
4802.55	12454.30	1180.43	-597.92	-450.20	1935.44	2.08	1.89	-478.42
5513.42	12829.90	1558.45	-751.82	-502.73	1931.75	1.93	1.92	-507.34
2841.00	12043.60	1359.93	-849.49	-165.04	1930.52	1.94	1.77	-538.19
11199.30	13935.20	1948.04	-420.22	-59.99	1932.37	1.97	1.80	-480.35
8038.24	13275.80	1704.29	-529.19	-165.04	1932.98	2.00	1.82	-513.13
9289.23	12812.30	1937.15	-737.35	-262.60	1932.37	2.01	1.83	-534.34
13164.70	11577.60	2510.45	-1117.63	-420.19	1931.75	2.05	1.87	-530.48
15034.40	12991.90	2556.64	-792.06	105.11	1931.75	2.07	1.91	-488.06
14774.00	12974.40	2493.51	-777.59	-330.14	1929.91	1.89	1.73	-491.92
12477.50	11562.50	2329.78	-1043.17	-390.17	1930.52	1.92	1.76	-516.98
7095.90	9683.47	2183.01	-1606.89	-307.62	1928.06	1.94	1.79	-563.26
14291.00	13404.30	2634.20	-762.82	510.33	1926.22	1.98	1.83	-495.77
19947.10	13118.80	3177.14	-803.37	322.73	1929.29	2.00	1.85	-509.27
20810.30	12915.30	3276.54	-804.15	22.56	1928.68	2.03	1.88	-522.77
18230.40	11279.90	3106.10	-1276.05	-202.57	1931.14	2.04	1.91	-495.77
13027.60	11077.70	2575.82	-1326.84	-67.49	1927.45	2.06	1.76	-457.21
6772.61	13539.60	1411.53	-746.24	0.05	1928.06	1.91	1.78	-528.55
9626.06	13086.10	1724.39	-714.44	-307.62	1928.68	1.93	1.80	-549.76
10731.50	12937.90	1875.48	-778.65	-427.69	1931.75	1.96	1.81	-505.41
6116.16	12490.80	1331.27	-1031.26	-472.72	1928.06	1.98	1.85	-516.98
-220.69	11646.70	783.87	-1205.51	-435.20	1929.29	2.01	1.89	-536.26
-247.20	12866.30	625.30	-750.76	-420.19	1929.29	2.04	1.91	-522.77
6573.58	12696.80	1549.23	-890.49	-480.22	1930.52	2.05	1.75	-486.13
11086.60	12229.50	1937.60	-1188.62	-555.26	1929.29	2.03	1.78	-430.22
7974.14	12715.60	1542.24	-874.96	-435.20	1928.06	1.92	1.82	-482.28
-408.44	11122.90	1293.39	-1115.82	-427.69	1929.29	1.94	1.83	-592.18
3488.35	10860.40	1302.75	-1303.18	-472.72	1931.14	1.98	1.84	-540.12
2833.28	11292.50	1203.09	-1410.49	-615.30	1929.91	2.00	1.87	-520.84
7608.61	13169.00	1362.05	-906.76	-630.31	1927.45	2.02	1.91	-507.34
2680.64	13140.20	691.35	-727.85	-457.71	1928.68	2.04	1.76	-486.13
-3425.02	12723.10	350.73	-694.99	-450.20	1929.29	2.07	1.79	-518.91
-888.22	12520.90	858.70	-745.79	-397.67	1930.52	1.89	1.80	-507.34

7023.88	12970.60	1337.21	-867.57	-487.73	1927.45	1.93	1.82	-515.05
8709.24	13653.90	1581.00	-623.09	-450.20	1927.45	1.97	1.86	-524.70
2071.07	13513.20	1278.92	-507.34	-112.51	1927.45	1.99	1.89	-518.91
1615.14	12264.70	1305.03	-783.17	-210.07	1929.29	2.00	1.75	-530.48
66.88	11498.50	995.87	-1269.72	-442.70	1929.29	2.01	1.76	-522.77
3383.20	12375.20	1185.68	-1184.40	-427.69	1926.22	2.04	1.80	-495.77
5691.68	13326.10	1711.55	-632.59	195.16	1926.22	2.05	1.83	-507.34
11840.70	12867.60	2505.02	-720.77	-382.67	1927.45	1.93	1.83	-459.14
12421.90	12900.20	2578.32	-809.70	-300.12	1928.06	1.94	1.86	-489.99
13031.00	11941.90	2527.36	-1107.08	-382.67	1928.06	1.96	1.88	-528.55
12658.70	12111.40	2707.56	-967.36	75.09	1928.06	2.01	1.87	-484.21

APPENDIX F

APPENDIX F. SOIL DATA

SOURCE : Soil Survey of Ingham County, Michigan.

SOIL NAME : Riddles (Fine loamy, mixed Mesic Typic Hapludefs)

PHYSICAL AND CHEMICAL PROPERTIES:

Depth : 0 to 22 inches

Permiability : 20 to 60 in/hr

Available water capacity: 0.13in/in

ENGINEERING PROPERTIES:

USA Texture : Sandy loam

Liquid limit% : 20 to 30

Plasticity Index : 2 to 10

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