THREE-DIMENSIONAL INTERFERENCE
BETWEEN TWO TILLAGE TOOLS

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1967

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1970

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ACKNOWLEDGMENTS

The research herein reported was partially supported by funds from the Cooperative State Research Service.

Many people at the Oklahome State University Stillwater Campus and at the Oklahoma Cotton Research Station in Chickasha were of aid in the carrying out of this research program. I would like to thank particularly Professor Jay G. Porterfield, adviser and committee chairman; Dr. James E. Garton, Dr. Lawrence O. Roth, Dr. Henry R. Sebesta and Dr. John F. Stone, committee members; Professor Ervin W. Schroeder, Head of the Agricultural Engineering Department; Mr. David G. Batchelder, Associate Professor of Agricultural Engineering; Mr. Galen McLaughlin, Shop Foreman at Chickasha; Mr. Jack I. Fryrear, Head Draftsman at Agricultural Engineering; Glen W. Smith and Michael L. Calavan, undergraduate part-time employees; and Lonnie I. Sumpter, shop worker at the Agricultural Engineering Laboratory in Stillwater.

In addition, I would like to thank my thesis typist, Mrs. Patrick Metz.

Finally, I wish to offer very special thanks to my wife, Virginia, for her support and encouragement.

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CHAPTER I

INTRODUCTION

Large amounts of energy are used in soil tillage. In 1961, sixty percent of the tractor power that was expended on farms in the United States was used to operate soil loosening or turning tools, and required more than 2 billion gallons of fuel costing 323 million dollars (5). Many of our tillage systems are inefficient and have been improved little over the past tens and even hundreds of years. In this context, an efficient tillage system is one which minimizes the amount of energy required to till the soil, consistent with achieving a desired soil condition. Tillage system improvements, which have been made, were often the result of a slow evolution or were developed through a trial-and-error approach. However, with the aid of analysis and experimental design techniques, tillage systems can be quantitatively characterized and improvements indicated.

The research herein described was related to the general problem of trying to improve tillage system efficiency. A solution to the overall problem was not attempted, but rather a tillage system involving interference between simple shape tools was studied, and certain features of its operation were quantitatively characterized. Interference relationships associated with this tillage system give some indications of the ways in which interference can be utilized to improve tillage system efficiency.

When two or more tillage tools are operated sufficiently close together, interference occurs. That is, the operation of at least one of the tools is influenced by the presence of the other tool(s). Interference may affect the amount of energy required to till the soil to a given condition, offer the possibility of creating a different final soil condition than would be obtained without interference, and impose clearance limitations for passage of large clods and trash.

A soil bin study was conducted of three-dimensional interference between two flat plate tillage tools operating in an artificial soil.

The general objective of this investigation was to study and characterize selected aspects of interference between tillage tools.

One tool of 3-inch width (the dynamometer tool) was operated 5 inches deep in soil moving at velocity V. Basic interference conditions were specified in terms of the independent variables which gave the three-dimensional position of a second tool (the interfering tool) with respect to the dynamometer tool. Other independent variables were also included in the experimental program so that their roles in interference could be explored. These independent variables were associated with the orientations of the tools, the width of the interfering tool, and the velocity of the soil. The wrench which the soil applied to the dynamometer tool was the dependent variable for interference effects. A wrench consists of a force and a couple in a plane perpendicular to the force.

CHAPTER II

REVIEW OF LITERATURE

In order to provide background information, the following topics are discussed: soil bins and artificial soils, soil forces on individual tillage tools, and interference between tillage tools.

Soil Bins and Artificial Soils

In field testing of tillage machines, a researcher often experiences difficulty in maintaining the soil in the test field at the desired pre-test condition. The soil condition may vary throughout the field, and its condition may change with the passage of time. In addition, the weather often interferes with testing programs. These problems combine to make field testing of machines difficult and, many times, inconclusive. Uncontrolled changes in soil condition may affect test results more than do changes in design of the machine.

Numerous researchers have found that they can better study soil-machine interrelationships under carefully controlled conditions using a laboratory soil bin (1, 3, 10). Soil bin facilities for testing tillage machines generally consist of (a) a soil container, (b) a dynamometer carriage and associated instrumentation, and (c) soil processing equipment.

Researchers have published several papers that deal with soil bin design and instrumentation (4, 7, 17). Siemens and Weber (17) pointed out many of the important considerations involved in the development of soil bin facilities. They outlined (a) the advantages and disadvantages of circular and straight soil containers, (b) factors to consider in choosing between a stationary and moving test carriage arrangement, and (c) the importance of transverse rigidity of the test carriage with respect to the soil.

Researchers badly need a method of selecting the size of soil container in relation to the size tillage machine they plan to test. If the depth and/or width of the soil container is too small in comparison with the size, shape, and loads on the contact surfaces of the tillage machine, boundary conditions on the sides and bottom of the soil container will affect the test results. The result is not so serious if the soil container depth and/or width dimensions are much larger than necessary for eliminating significant boundary effects. The soil container being larger than necessary means simply that a larger amount of soil must be prepared for each test. The larger amount of soil results in increased time for soil preparation and increased soil processing problems.

Harrison (7) stated that a soil container width to depth ratio of 3:1 gives satisfactory results and that the container dimensions must be sufficiently large to prevent side and bottom effects. It is unfortunate that researchers have not done more to determine satisfactory size relationships between the tillage machine and the soil container.

Considerable attention needs to be directed towards the design of soil processing equipment, or many of the potential advantages of soil bin testing may not be realized. This equipment should have the capability of (a) completely destroying the effects of prior soil deformation and manipulation, (b) placing the soil back in the soil container so that the soil strength properties are uniform throughout the test zone, (c) producing various desired states of soil compaction, and (d) processing soils with a minimum amount of operator attention.

Researchers have used both natural and artificial soils in soil bins. Artificial soils are being used to a greater extent due to difficulties in maintaining constant strength properties with natural soils. Soil processing equipment rapidly dries out natural soils. The phenomenon of remolding or weakening of the soil with mechanical working is also present in natural soils, particularly the more cohesive soils.

Hanomoto (6) indicated several characteristics that an artificial soil should have; these are:

1. The strength properties of the soil should not change with time, temperature, or humidity.
2. The soil mix should be capable of representing a wide range of soil types and soil conditions.
3. The soil should have reproducible soil properties.
4. The artificial soil should behave reasonably like a natural soil.

The two most common artificial soils are the clay-sand-oil mix and the clay-sand-ethylene glycol mix. Both have shortcomings when one considers the above ideal characteristics. Korayem and Reaves (9) used both types of artificial soils in connection with tillage machine tests. They were able to vary the ethylene glycol concentration and produce changes in the cohesive properties of the mix. However, when they used spindle oil, the cohesive properties did not change significantly with the concentration. Spindle oil provided excellent long term stability due to the slow evaporation rate of the oil and the fact that losses of oil did not affect the strength properties. Ethylene glycol had a serious deficiency as a wetting agent, since it was hygroscopic. Changes in the relative humidity, therefore, affected the properties of the soil due to changes in moisture content of the mix.

Soil Forces on Individual Tillage Tools

A number of researchers have explored the relationships between soil forces on an individual tillage tool and independent factors associated with the soil-tool system.

Rowe and Barnes (16) examined the way in which speed influenced the draft force on a tillage tool. They conducted tests in a soil bin which involved a moving soil box and a stationary dynamometer. Four natural soils were used in their tests: sand, Ida silt loam, Colo silty clay loam, and Luton silty clay. The tillage tool used was a flat plate 2 inches long, 4 inches wide and inclined at 25 degrees to the horizontal, such that the bottom edge of the tool was leading. They found that as the velocity was increased from 0.75 feet per second to 2.75 feet per second, the draft in the sand increased approximately 15 percent, and the draft in the Colo silty clay loam increased approximately 60 percent. When they made analytical calculations of draft, they found that acceleration of the soil contributed only a small part of the total draft force. Increase in draft with speed was due mainly to increased shear strength of the soil at a higher rate of shear. It had previously been thought that the draft increase with speed increase could be reduced by shaping the tool so that the soil would be subjected to lower acceleration. The results of this study indicated that reducing the acceleration of the soil acted on by the tool would only result in a small reduction in the draft increase.

Payne (12) studied a tillage system involving a vertical rectangular flat plate tool operated in several soils at various speeds. He attacked the problem both analytically and experimentally. In the analytical portion of the study, he examined the way in which the soil was behaving in the vicinity of the tool, and then developed analytical equations to characterize the operation of the soil-tool system. He also measured the draft force on the tillage tools. He studied mainly narrow tools with depth/width ratios lying between 25:1 and 1:1. He worked with several soil types: sand, sandy loam, and three different clay loams. The tools were operated at speeds ranging between 0.73 and 8.8 feet per second. For this simple tillage system, he was able to develop workable analytical relationships. One of the most important aspects of his study involved his examination of the soil behavior near the tillage tool.

Based on his studies, Payne arrived at several important conclusions:

1. A wedge-shaped block of soil will be isolated on the front of a moving tool by two vertical plane surfaces of slip and an inclined bottom surface which is slightly curved. The inclination of the bottom surface to the horizontal will depend upon the soil/metal angle of friction and the soil's angle of internal friction, but will never be less than zero.

The wedge will move forwards as if part of the tool, but at the same time will slide slowly up the tool surface.

2. The wedge will act as a knife splitting the surrounding soil in half and pushing it sideways and upwards to form a passage for itself. The soil so treated will be isolated from the bulk of the soil along an inclined surface of slip which rises from the bottom of the wedge and emerges at ground level to form a crescent-shaped crack surrounding the tool and the wedge.
3. The continuous movement of the tool produces a series of slip-stick compressions and shear failures within the soil.
4. The distance from the tool to the crescent crack is directly proportional to depth of tool operation.
5. Draft force is a function of depth. This function has two important components, one which is proportional to depth, while the other varies as the square of the depth. For agricultural soils and depth/width ratios below 4, the latter component is small. For cohesionless soils such as dry sand, the former component is small.
6. For tools wide enough to bring the soil into plastic equilibrium (approximately 2 inches), the distance beyond the side of the tool to which the soil was disturbed was insensitive to tool width.
7. For tools wide enough to bring the soil into plastic equilibrium, one component of draft force is proportional to width, while another is independent of width.
8. For tools wide enough to bring the soil into plastic

equilibrium, the radial dimensions of the limit of upheaval can be predicted from the parameters soil cohesion and angle of internal friction, adhesion and angle of soil/metal friction and the soil bulk density.

9. Draft force varies almost linearly with cohesion, and volume of upheaval is dependent upon angle of internal friction and angle of soil/metal friction.

In a subsequent study, Payne and Tanner (13) examined a similar tillage tool system, except that rather than the tool remaining vertical, it was operated at various rake angles. Rectangular flat plate tools covering the range of inclination to the horizontal 20^{o} to 160^{o} and the range of depth/width ratios 1.5:1 to 6:1 were drawn through various soils in the field and in the laboratory. The results of measurements of the extent to which the soil was disturbed and the magnitudes and directions of the resultant forces on the tools were presented. This investigation was empirical and did not involve analytical development of equations. By way of orientation, a rake angle of less than 90^{o} indicated that the bottom edge of the tool was leading, while a rake angle of 90^{o} indicated a vertical tool.

They found that the pattern of soil cleavage around rectangular flat plate tools which were inclined to their direction of travel was generally similar to that around vertical tools over the range 20^{o} to 160^{o} inclination to the horizontal. The most notable differences were that the crescent-shaped body of disturbed soil surrounding the tool was elongated or foreshortened, depending upon whether the bottom of the tool led or trailed, and the small wedge of soil which, with a 90^{o} inclination rises up the face of the tool, remained static for much of the time at about 100° and was not visible on the surface for greater inclinations. Changes in draft force due to the proportions or angle of inclination of the tool were found to be closely correlated with changes in length of the shear path in the direction of travel. As with a vertical tool, it was found that the distance beyond the sides of the tool to which the soil was disturbed was insensitive to tool width, provided this was greater than 2 inches. The efficiency of the tools measured in terms of the draft force and the width of disturbed soil hardly varied with the proportions of the tool, but was sensitive to rake angle, being approximately 8 times greater at an inclination of 20° than at 160°. One component of draft force was proportional to tool width, while another, which became progressively larger for the more obtuse inclinations, was independent of width. Draft force was relatively insensitive to inclination between 20° and 50°, but thereafter, increased very rapidly. With the tool inclined at less than 45°, the soil provided a component force to assist penetration, but at greater angles, it opposed penetration. The resultant force on a vertical tool was inclined upwards at about 20° to the horizontal.

Kaburaki and Kisu (8) evaluated the effects which rake angle α and side angle β have on draft force for a flat plate tillage tool. In their studies, a rake angle of less than 90° indicated that the bottom edge of the tool was leading, and a value of 90° indicated that the tool was vertical. A side angle of 90°, at a rake angle of 90°, placed the tool surface perpendicular to the direction of travel. The projected area of the tool in the direction of travel was maintained rectangular and constant for all cases studied, and soil was moved laterally into an open furrow. Tests were set up in a factorial arrangement so that interactions between α and β could be evaluated. Both angles were varied between 20° and 90°. The draft was influenced to a greater extent by the rake angle than by the side angle. The draft was approximately doubled when the rake angle was increased from 20° to 90°. Increases in the side angle β decreased draft until an angle of approximately 45° was attained. After that point, draft became essentially constant for a given value of α. In no case, did the draft decrease exceed 25 percent as side angle was varied.

Interference Between Tillage Tools

With reference to interference between tillage tools, two types of interference need to be considered. Simultaneous interference occurs when two or more tools are operated sufficiently close together such that the action of each tool is simultaneously influenced by the presence of the other tool(s). Boundary condition interference occurs when the interference between tools is not simultaneous, but rather, the boundary condition created by one tool influences the action of another tool which operates in the same vicinity at another time.

Some work has been done in the area of interference between tillage tools, but much remains to be learned regarding interference relationships. An important factor involved with interference, especially simultaneous interference, is that the actions of the tools need to be studied while interference is actually occurring. The actions of two tools cannot be studied separately and then their combined action predicted based upon their separate actions.

Zelenin (18) studied teeth on an experimental dragline scoop.

The scoop had a volume of 0.38 cubic meters and was operated at various angles of inclination to the horizontal. Teeth of width m were placed along the leading edge of the scoop at a spacing h from the side of one tooth to the side of another tooth. The scoop was operated in clay and loam soils. With teeth on the scoop, less force was required to move the scoop through the soil as compared to a scoop with no teeth. Further, it was found that a definite minimum force existed for a h/m value of approximately 2.5 which resulted in an operating force about 40 percent less than the operating force required without teeth. Interference between teeth and cutting blade was clearly demonstrated. Both simultaneous and boundary condition interference were likely involved in this soil-machine system.

Reed and Berry (15) studied interference associated with a double-cut plow. Their double-cut plow consisted of one plow operated above and offset sideways from the other, such that two layers of soil were plowed, but not mixed with one another. In operation of the double-cut plow, the lower share moved soil upward into an unconfined area. As a result, the same volume of soil could be tilled in layers with less energy than was required to till it in a single cut. In their study, approximately 25 percent less draft force was required with the double-cut plow, as compared to the single-cut plow, when the same volume of soil was being tilled. It can be seen that boundary condition interference was the principal type involved in this soil-tillage system.

Rathje (14) conducted studies concerning interference between two vertical straight tools. The draft resistance of the two tools, each with a width of 15 millimeters and a length of 60 millimeters from front to rear, was found to depend on the ratio of the distance between tools b and the depth of operation t. When the tools were close together, a common compression wedge was formed similar to that in front of a single tool of the same overall width. When the tools were gradually moved apart, the resistance for a given depth increased and reached a maximum for the system when b = 0.043t. As the tools were moved further apart, the compression wedge that had bridged over the gap between the two tools was broken through at the bottom, and soil flowed between the two tools. The draft force dropped rapidly with an increase in the spacing between the tools and reached a minimum value at b = 0.34t, where it was only 10 percent higher than that of a single tool. As the distance between the tools was increased still further, the draft increased until the point b = 2.5t was reached, and the tools were acting independently. In Rathje's study, simultaneous interference was acting.

CHAPTER III

DEVELOPMENT OF EXPERIMENTAL PROGRAM

A description of the main experimental program is presented first, and then the reasons for selection of this program are discussed. The selection procedure is discussed in two parts: selection of system configuration, variables, and experimental design; and selection of system operating values. Finally, for the system selected, the specific objectives of the investigation are stated.

Description of Experimental Program

By progressively making selections, an experimental program was developed; this program is now presented. Refer to Figure 1, where appropriate, to identify quantities being discussed.

<u>Tool Shape</u>: Flat rectangular plate, 3/4" thick

<u>Experimental Design</u>: Complete factorial

<u>Dependent Factor</u>: Wrench on the dynamometer tool; ω

<u>Independent Factors</u>: (8 factors: 2V, 2w, 2α, $2\beta_d$, $2\beta_i$, 2x, 5y, 2d)

A. Soil velocity; V = 1 fps, 3 fps

B. Width of interfering tool; w = 2", 4"

C. Orientation of tools

$\alpha = 75^\circ, 105^\circ$

$\beta_d = 75^\circ, 105^\circ$

$\beta_i = 75^\circ, 105^\circ$

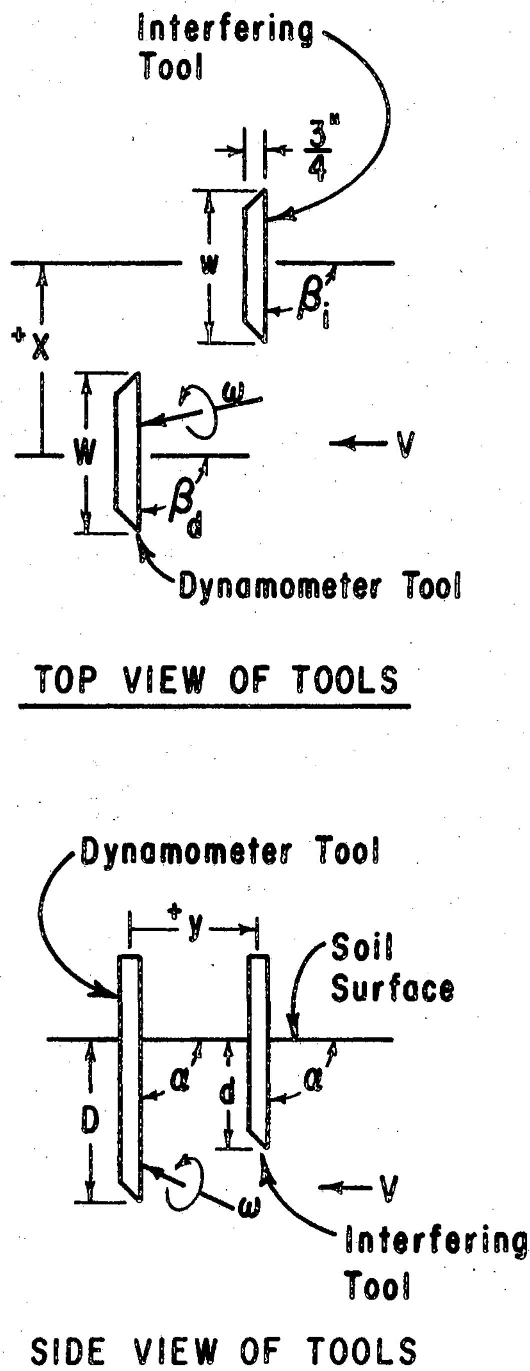


Figure 1. Tillage System Which was Studied

D. Position of interfering tool

x = 2.5", 5.5"

y = -15", -4", +4", +8", +15"

d = 4", 6"

Constants

A. Width of dynamometer tool; W = 3"

B. Depth of dynamometer tool; D = 5"

C. Pre-test condition of soil; uncompacted soil with a density of 79 lb/ft^3.

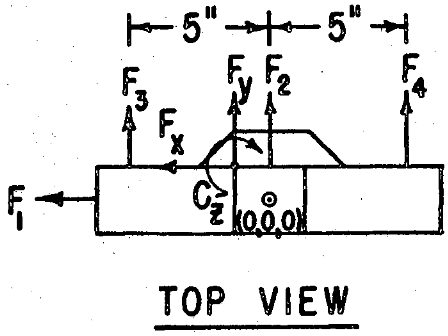
The dependent factor was a wrench ω which the soil applied to the dynamometer tool. The wrench consisted of a force F and a couple C in a plane perpendicular to the force. The force was also considered as components F_x, F_y, and F_z. The couple C was, likewise, also considered as components C_x, C_y, and C_z. Refer to Figure 2 for identification of quantities being discussed. It was also necessary to locate the line of action which was specified by the wrench. The line of action of F was located by its intersection with the dynamometer tool and was given by TX and TZ. This line of action for F represented the true line of action of the soil-tool resultant force, since the couple so specified was the minimum couple which could have placed the system in equilibrium (5).

Selection of System Configuration, Variables, and Experimental Design

Gill and Vanden Berg (5) indicate that the generalized tillage relation can be mathematically represented by the two equations

Notes:

1. Forces are measured in pounds.
2. Couples are measured in inch-pounds.
3. Distances are measured in inches.
4. F_1, F_2, F_3, F_4, F_5, and F_6 are load cell forces.
5. F_x, F_y, and F_z are the forces that the soil exerts on the tillage tool.
6. $F = \sqrt{(F_x)^2+(F_y)^2+(F_z)^2}$
7. C_x, C_y, and C_z are the couples that the soil applies to the tillage tool.
8. $C = \pm\sqrt{(C_x)^2+(C_y)^2+(C_z)^2}$, such that C in vector representation is positive when it is in the same direction as F, and negative when it is in the direction opposite to that of F.



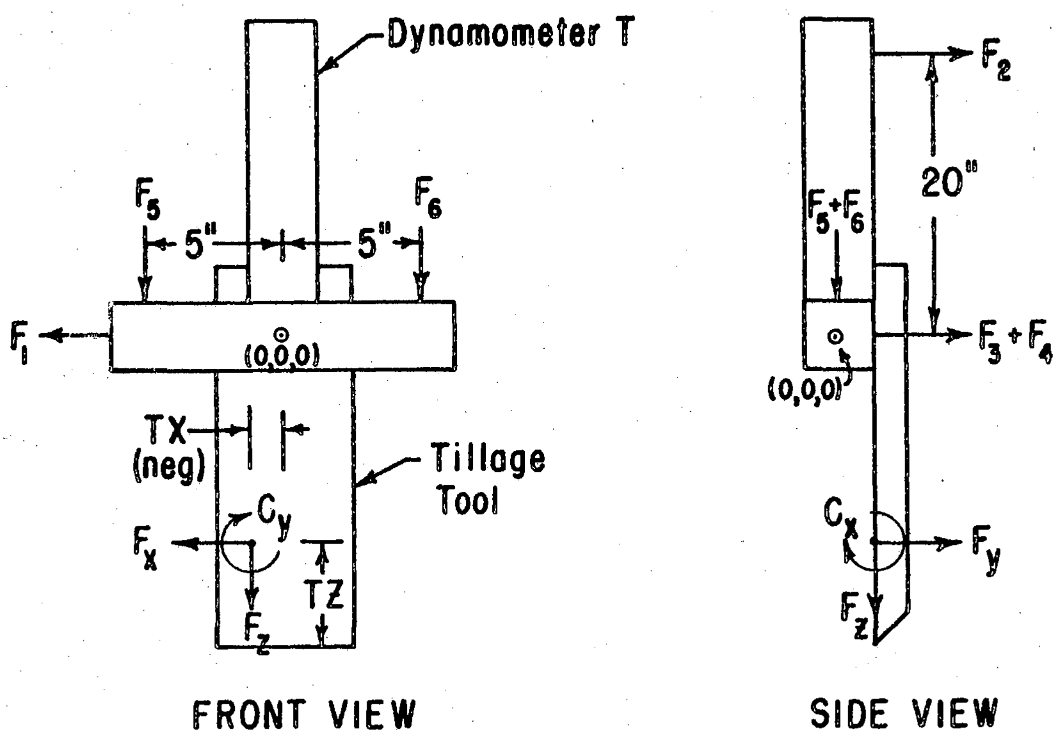


Figure 2. Location of Forces on Dynamometer T and Dynamometer Tillage Tool

$$R = f(T_s, T_m, S_i, I)$$

$$S_f = g(T_s, T_m, S_i, I)$$

where R = forces on the tool to cause movement

T_s = tool shape

T_m = manner of tool movement

S_i = initial soil condition

I = interference

S_f = final soil condition

In considering the generalized tillage equations, it is important to bear in mind that each quantity listed may actually be a collection of quantities.

These generalized equations provide a goal for tillage research. If the functional relationships were known, these equations could be used directly to improve the efficiency of tillage systems. That is, given S_i, f, g, and a desired S_f; T_s, T_m, and I could be determined such that R would be minimized. Since f and g are not known, these equations cannot yet be used directly for the design of tillage systems. However, the equations can be used as a guide in planning and interpreting tillage studies.

The experimental program was developed in steps by progressively making selections. At each stage in the development, consideration was given to the various alternatives, and then a selection was made. This selection procedure was aimed at developing an efficient experimental program which would yield the greatest amount of new information for a given expenditure of effort.

The generalized tillage equations indicate that any or all of the independent quantities listed could be incorporated in an experimental program. However, the effects of some independent quantities have been studied to a greater extent than others. It was decided that three-dimensional interference between tillage tools would be studied. There were two reasons for this selection. First, interference is functionally related to R and S_f; the literature review indicates that interference can have large effects on R and S_f. Second, various forms of interference have been explored to some extent, but the general case of three-dimensional interference between tillage tools had not been studied and characterized.

In order to examine interference between tillage tools, it was necessary to study a tillage system which involved two or more tools. Since this was the first investigation of three-dimensional interference, a tillage system involving two tools was selected for study. Interference could be readily characterized and interpreted for this simplified system. Interference relationships associated with the more complex tillage systems were in need of study, but it was appropriate to first characterize interference in a simplified system.

With respect to shape of tools to study, a variety of shapes were considered, but a rectangular flat plate oriented generally perpendicular to the direction of travel was selected. Preliminary tests indicated that a body of compacted soil would likely form on the leading surfaces of many tool shapes, so that the exact shape of the tool would become somewhat irrelevant. Figure 3 shows soil bodies that formed on square and round bars.

Once the tool shape had been selected, its depth/width

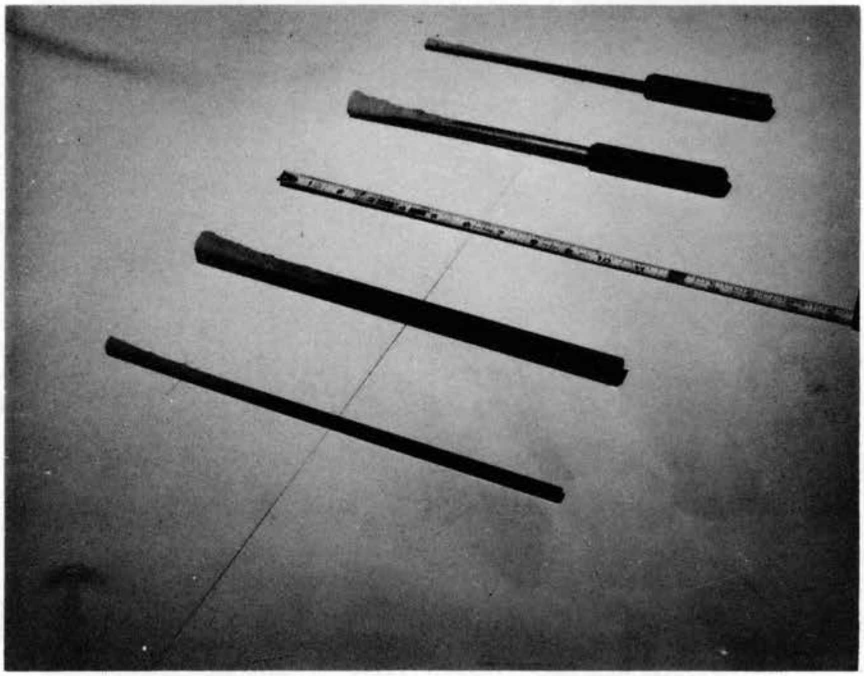


Figure 3. Soil Bodies Which Were Formed on Round and Square Bars

proportions were considered. It was decided that the depth/width ratios associated with the tools would be 1 or greater so that the tools could be classed as narrow tillage tools with reference to Payne's criteria (12). Payne indicated that narrow tillage tools were more representative of agricultural implement components than were wide tillage tools which would have depth/width ratios of 0.5 or less. It would be desirable to operate in either the narrow tool class or in the wide tool class, but not in both classes for a given experiment, since the soil near the tillage tool would behave differently for the two classes.

The development of the experimental program, thus far, can be summarized by indicating that three-dimensional interference between two rectangular flat plate tillage tools has been selected for study. At this point, the pertinent quantities associated with this system can be listed in an expanded form, and then the selection procedure can be continued by deciding which quantities will be variables and which ones will be held constant.

The pertinent quantities for this system are now listed. Refer to Figure 1 for aid in identifying quantities.

1. ω = wrench on dynamometer tool
2. x = transverse location of interfering tool with respect to dynamometer tool
3. y = longitudinal location of interfering tool with respect to dynamometer tool
4. d = depth of interfering tool
5. β_d = side angle of dynamometer tool
6. β_i = side angle of interfering tool

7. α_d = rake angle of dynamometer tool

8. α_i = rake angle of interfering tool

9. w = width of interfering tool

10. V = velocity of soil

11. γ_d = tilt angle of dynamometer tool (this angle could be associated with rotation of the tool about the y-axis)

12. γ_i = tilt angle of interfering tool (this angle is defined in the same manner as γ_d)

13. W = width of dynamometer tool

14. D = depth of dynamometer tool

15. S_i = initial soil condition

16. S_f = final soil condition

17. ω_i = wrench on interfering tool

The quantities ω, x, y, and d were selected as a minimum set which could be used to study three-dimensional interference. That is, it might be considered that x would be associated with transverse interference, y would be associated with longitudinal interference, and d would be associated with vertical interference. The dependent quantity ω was selected to assess the effects of interference. In this minimum set, ω could have been replaced by ω_i or S_f, and d could have been replaced by D. The reasons for not including ω_i, S_f, or D are discussed later in this section.

Two criteria were used to help decide which additional pertinent quantities would be included in the experimental program. First, it was desired to incorporate additional quantities in the experimental program if they would help characterize interference. Second, it was desired to incorporate additional quantities in the experimental program if they allowed this simplified tillage system to be more readily related to conventional tillage systems.

Considering Figure 1, it could be visualized that the side angles β_d and β_i would affect interference, since the varying of the side angles of the tools would influence the flow of soil past the tools. That is, setting a tool at a side angle of other than 90^o would result in more soil being directed to one side of the tool than the other. Consequently, if two tools were operated near one another, the side angles could be expected to influence the interference patterns. Furthermore, tillage tools such as the moldboard plow sweep soil sideways and their configurations could, therefore, be associated with side angle. It should be emphasized that the principal reason for including β_d in the experimental program was so that its effects on interference could be examined. Other researchers have already studied the main effects of β_d on tillage tool forces.

Considering Payne and Tanner's work (13), it could be expected that rake angle would affect interference. If a tool were operated at two different rake angles α, one less than 90^o and one greater than 90^o, the tool's action and the behavior of the soil in its vicinity would be somewhat different for the two cases. For rake angles less than 90^o, the tool would be lifting the soil and allowing it to flow freely around the sides of the tool. While with rake angles greater than 90^o, the tool would be applying more of a downward component to the soil, causing the soil to force its way past the tool much less freely. Considering two tools operated near one another, it would be expected that interference patterns would be somewhat different for the two values of rake angle, since soil flow would be more impeded in the one case. Furthermore, rake angle could be associated with tillage system components such as the chisel. It was decided that the same value of rake angle would be used for both the dynamometer tool and the interfering tool, because this situation would be more frequently found in conventional tillage systems. In addition, operating the tools at separate values of rake angle would complicate the specification of y in an appropriate manner. As with β_d, it should be emphasized that the principal interest in α was its effects on interference. The main effects of α_d on tillage tool forces have already been studied by other researchers.

At first, it might appear inappropriate to include w as a variable, since Payne (12) found that the distance to which the crescent-shaped volume of soil extended beyond the side of a tool was relatively insensitive to tool width. However, in an interference situation, tool width should be considered, since interference occurring at one side of a tool would force more soil to flow around the other side of the tool, and the ease of forcing soil to the opposite side of the tool would be related to the tool width.

In preliminary tests it was observed that soil velocity V influenced the pattern of soil flow around on individual tool. At a velocity of 3 feet per second, the soil was swept out to the sides of the tool, and a deep open void, extending almost to the bottom of the tool, formed behind the tool. At 1 foot per second, the soil was not swept as far to the sides of the tool, and soil flowed in behind the tool leaving very little void behind the tool. Considering these observed flow pattern differences caused by soil velocity, it was hypothesized that soil velocity would affect interference patterns, and therefore, soil velocity was included as a variable in the experimental program. As with β_d and α , it should be emphasized that the principal interest in V was its effects on interference. The main effects of V on tillage tool forces have already been studied by other researchers.

Tilt angle of the dynamometer tool γ_d was not included as a variable. Considering the infinite plane containing the front surface of the dynamometer tool, α_d and β_d would be sufficient to specify any orientation of this plane, and therefore, γ_d would be somewhat redundant. Since the tool surface was not an infinite plane, γ_d could have been included as a variable. However, it was omitted in order to limit the size of the experiment and maintain an efficient experiment. By the same reasoning, tilt angle of the interfering tool γ_i was not included as a variable.

The width of the dynamometer tool W was not included as a variable. So long as both tillage tools had the proportions of narrow tillage tools, the varying of the width of one of the tools was sufficient. It might be considered that the effects of the ratio w/W were being examined, and it would, therefore, be unnecessary to vary both tool widths. By the same reasoning, the depth of the dynamometer tool D was not included as a variable. In addition, it was more appropriate to vary w and d, since varying of W and D would have main effects on the dependent wrench which would not be related to interference. However, the main effects of varying w and d would be related to interference. The main effects of W and D on tillage tool forces have already been studied by other researchers.

Consideration was then given to the initial soil condition S_i and

and final soil condition S_f. Initially, it had been hoped that the cross-sectional area of soil disturbed by the tillage tools could be identified; however, this was not accomplished. It had been planned that the soil would be compacted before reaching the test area. Then, after the tools had passed through the soil, a cross-sectional area of reduced density soil could be located and identified as the cross-sectional area of soil disturbed by the tools. In preliminary work, considerable attention was directed towards compacting the soil in a feasible manner, but with little success. Some compaction of the soil was achieved, but not a sufficient amount to make possible the separation of the disturbed and undisturbed portions of the soil. In view of the results from the preliminary compaction studies, it was decided that an uncompacted soil would be used in the experimental program, and that no attempt would be made to quantitatively identify the cross-sectional area of soil which was disturbed by the tools. Therefore, S_i and S_f were not included as variables in the experimental program.

The wrench on the interfering tool, ω_i, was not included as a dependent variable in the experimental program. It would have been somewhat redundant to include ω_i since ω yielded some information about forces on the interfering tool. It might be considered that the roles of the tools would be switched as the interfering tool moved from a negative y value to a positive y value, and therefore, some information would be obtained about forces on the interfering tool. As discussed with reference to widths and depths of tools, it would be more appropriate to measure the dependent wrench on one tool and vary the width and depth of the other tool, rather than having all three variables associated with the same tool. Therefore, ω rather than ω_1 was selected as the dependent variable.

When the system configuration and variables had been selected, it was necessary to organize the variables in an experimental program. A similitude analysis was considered as a possible aid in organization of the experiment. Considering the force component F of the dependent wrench, the following pi terms were developed for this system. Only the dependent pi term and the independent pi terms which would be varied, are presented.

$$\pi_1 = \frac{F}{\rho N_e V^2 W D}, \quad \pi_2 = \frac{N_e V^2}{G D}, \quad \pi_3 = \frac{w}{W}, \quad \pi_4 = \alpha$$

$$\pi_5 = \beta_d, \quad \pi_6 = \beta_i, \quad \pi_7 = \frac{x}{W}, \quad \pi_8 = \frac{y}{W}, \quad \pi_9 = \frac{d}{D}$$

where: ρ = pre-test density of soil, lb_m/in^3

N_e = Newton's Second Law Coefficient, $\frac{lb_f \times sec^2}{lb_m \times in}$

G = gravitational constant, lb_f/lb_m

Other quantities are as defined previously

There are two principal reasons that similitude analyses are used. First, grouping the pertinent quantities often reduces the number of terms which need to be varied in the experimental program. Second, using pi terms in the experimental organization may allow the experimental results to be more readily applied to systems other than the specific system which was studied.

Considering the experimental system which has been selected for study, it appeared that little would be gained by using the similitude approach, and perhaps, the analysis would even be complicated. In this system, the same number of terms would need to be dealt with, whether pi terms or the individual quantities were used. With respect to the second purpose of similitude analysis, in this investigation it was not intended that the results would have direct application to other systems, but rather, it was intended that interference relationships associated with this system would give some indications of the ways in which interference could be utilized to improve tillage systems. Therefore, the similitude approach was not used in organization of the experimental program. Instead, a complete factorial arrangement of the independent variables was used. This experimental arrangement allowed the examination of interactions, as well as, main effects.

Selection of System Operating Values

Preliminary tests were conducted to help decide on the size and proportions of tools that would be studied. The tools would need to have depth/width ratios of 1 or greater. The tools would also need to be of large enough size such that variation of the independent factors would produce measurable changes in the interference patterns, but the tools would need to be small enough so that tests could be conducted in the available soil bin test section which was 24 inches wide and had a soil depth of approximately 12 inches. For these tests, the system was operated under the following conditions: $V = 2$ fps, $\alpha = 90^{\circ}$, $\beta_d = 90^{\circ}$, and $\beta_i = 90^{\circ}$. The values of x and y were varied during the tests. A dynamometer tool 3 inches wide and operated 5 inches deep was found to be satisfactory. The size and proportions of the interfering tool are discussed later in this section.

With respect to the independent variables V, w, α, β_d, β_i and d, it was decided that each of these would have values above and below a central value, such that the values above and below would be in the same operating regime (same type of behavioral system) as the central value, but at the same time, it was planned that changing from the lower to the upper values would produce measurable changes in the interference patterns. The selection of the operating values for these variables was made with the aid of preliminary tests, but a certain amount of judgement was still required in selecting the values due to the many possible interactions between variables. In these preliminary tests, each of these factors was varied one at a time, and the effects of this variation on the amount of soil disturbed and the pattern of soil flow around an individual tool was observed. Operating values were selected such that for each factor there was an observable difference in the amount of soil disturbed and/or the soil flow patterns for the two operating values. It was then hypothesized that these operating values would be sufficiently different to cause measurable differences in the interference patterns. At the same time, for each of these factors it was observed that the soil behavior near the tool was not basically altered, and a soil body formed on the tillage tool for both operating values of each factor.

As discussed earlier in this chapter, values of V = 1 fps and V = 3 fps were found to be sufficiently different so as to cause differences in the soil flow pattern around an individual tool. Therefore, these values of soil velocity were selected as operating values. The selection of these operating values was somewhat arbitrary; however, they met the needs of the experiment, and these velocities seemed reasonable, considering the operating velocities of conventional tillage tools.

The central value of w was selected as 3 inches so that the effects of having an interfering tool either narrower or wider than the dynamometer tool could be evaluated. Values of $w = 2$ inches and $w = 4$ inches were found to be sufficiently different to have a considerable affect on the amount of soil disturbed by the tool, and therefore, these were selected as operating values for w. Likewise with d, the central value of 5 inches was selected so that the effects of having an interfering tool operating either shallower or deeper than the dynamometer tool could be evaluated. Values of $d = 4$ inches and $d = 6$ inches were found to be sufficiently different to affect the amount of soil disturbed by the tool, and therefore, these were selected as operating values for d. With respect to the size and proportions of the interfering tool, it was found that the dynamometer tool and the interfering tool could be satisfactorily operated together in the available soil bin test section with the operating values selected.

The central values of α, β_d, and β_i were established at 90^o so that the tools would be perpendicular to the direction of travel in their central positions. With an individual tool, it was found that values of 75^o and 105^o for α and β were sufficiently different to affect the pattern of soil flow around the tool. With β at 75^o or 105^o, it was observed that a larger amount of soil was flowing around one side of the tool. Changing α from 75^o to 105^o produced an observable change in the dimensions of the crescent-shaped volume of soil in front of the tool. Therefore, operating values of 75° and 105° were selected for α, β_d, and β_i.

For these preliminary tests in which operating values were being selected for V, w, α, β_d, β_i and d, the factors other than the one being studied, were held constant at their central values. The central values were V = 2 fps, w = 3", $\alpha = 90^\circ$, $\beta = 90^\circ$, and d = 5".

Consideration was then given to selection of operating values for x and y. If an interfering tool of approximately the same size as the dynamometer tool were operated in the vicinity of the dynamometer tool, the interference zones would be somewhat as indicated in Figure 4. Consider an interfering tool operating at a positive y of small value and a given value of x such that its presence would affect the forces on the dynamometer tool. If the value of y was gradually increased, a point would eventually be reached such that changes in y no longer caused changes in the forces on the dynamometer tool. At this point, the interfering tool would be moving from Zone I to Zone II. If a position of the interfering tool was such that its presence did not affect the forces on the dynamometer tool, then the interfering tool would be in Zone III.

The maximum value of x = 5.5" was selected such that with V = 1 fps, w = 2", $\alpha = 75^\circ$, $\beta_d = 105^\circ$, $\beta_i = 75^\circ$ and d = 4", there would still be a measurable change in the forces on the dynamometer tool as the y position of the interfering tool was varied from -9" through +15". The minimum value of x = 2.5" was selected so as to be representative of the region between x = 0 and x = 5.5".

The minimum value of y = -15" was selected so that no interference would occur with conditions set to provide maximum interference

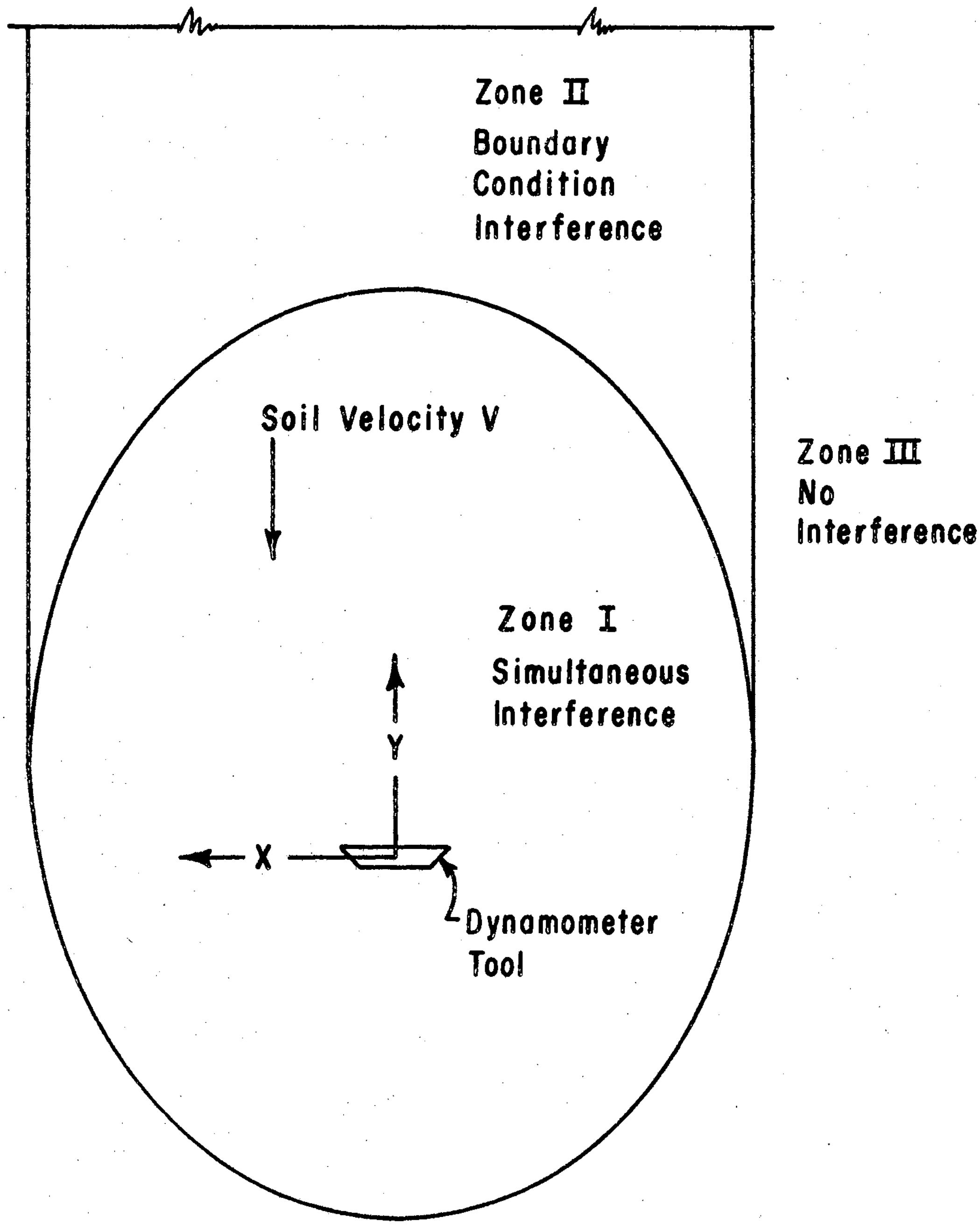


Figure 4. Interference Zones for the Tillage Tools

with $V = 3$ fps, $w = 4''$, $\alpha = 105^\circ$, $\beta_d = 75^\circ$, $\beta_i = 105^\circ$, $x = 2.5''$ and $d = 6''$. The value of $y = -15''$ represented a reference condition in which the interfering tool was not affecting the forces on the dynamometer tool. For this reference condition, the dynamometer tool was operated by itself, without the interfering tool being in the soil. The maximum value of $y = +15''$ was selected so that with maximum interference conditions or with minimum interference conditions ($V = 1$ fps, $w = 2''$, $\alpha = 75^\circ$, $\beta_d = 105^\circ$, $\beta_i = 75^\circ$, $x = 5.5''$ and $d = 4''$), this value of y would be near the line separating the zones of boundary condition and simultaneous interference. The value of $y = -4''$ was selected to provide a large amount of simultaneous interference with the interfering tool behind the dynamometer tool. The value of $y = +4''$ was selected to provide a large amount of simultaneous interference with the interfering tool in front of the dynamometer tool. The value of $y = +8''$ was selected to be representative of the region between $y = +4''$ and $y = +15''$.

The values of x and y selected, were representative of the left halves of the zones of interference. The right halves of the zones of interference were accounted for by symmetry.

Specific Objectives of the Investigation

For the system selected, the following were the specific objectives of the investigation:

1. For each dependent quantity (F_x, F_y, F_z, F, C_x, C_y, C_z, C, TX, and TZ), determine the percent of the total variation of the dependent quantity that can be attributed to each source of variation (V, w, α, β_d, β_i, x, y, d and their interactions).

2. For each dependent quantity, develop a prediction equation which relates the dependent quantity and the independent quantities. Each prediction equation should be fairly simple, yet account for a reasonably large percent of the total variation of the dependent quantity.

3. Display characterization of interference by use of graphic representations.

CHAPTER IV

EQUIPMENT AND PROCEDURES

In this chapter, the following topics are discussed: the soil bin, the tillage tools, the procedure for conducting the factorial program, the procedure for conducting each series, and the recording of data.

The Soil Bin

A soil bin was designed and built for use with this study, as well as, other subsequent studies. Figure 5 is a schematic diagram of this soil bin. Figures 6 thru 13 are photographs of various portions of the soil bin system. In operation, soil flows from the dynamic storage hopper, is carried along the test belt under the leveling blade and the compaction drum, past the density detector and into the test area. After passing the test area, the soil falls from the test belt onto the return belt. The return belt carries the soil over to the lift pulley which deposits the soil back into the dynamic storage hopper. The soil bin can be operated continuously for extended periods of time, thus allowing independent factors to be varied while observing their effects on the dependent factors. The test belt can be operated at speeds ranging between 0 and 8 feet per second. Six load cells are used in conjunction with a tillage dynamometer. The signals from these load cells are recorded on 6 channels

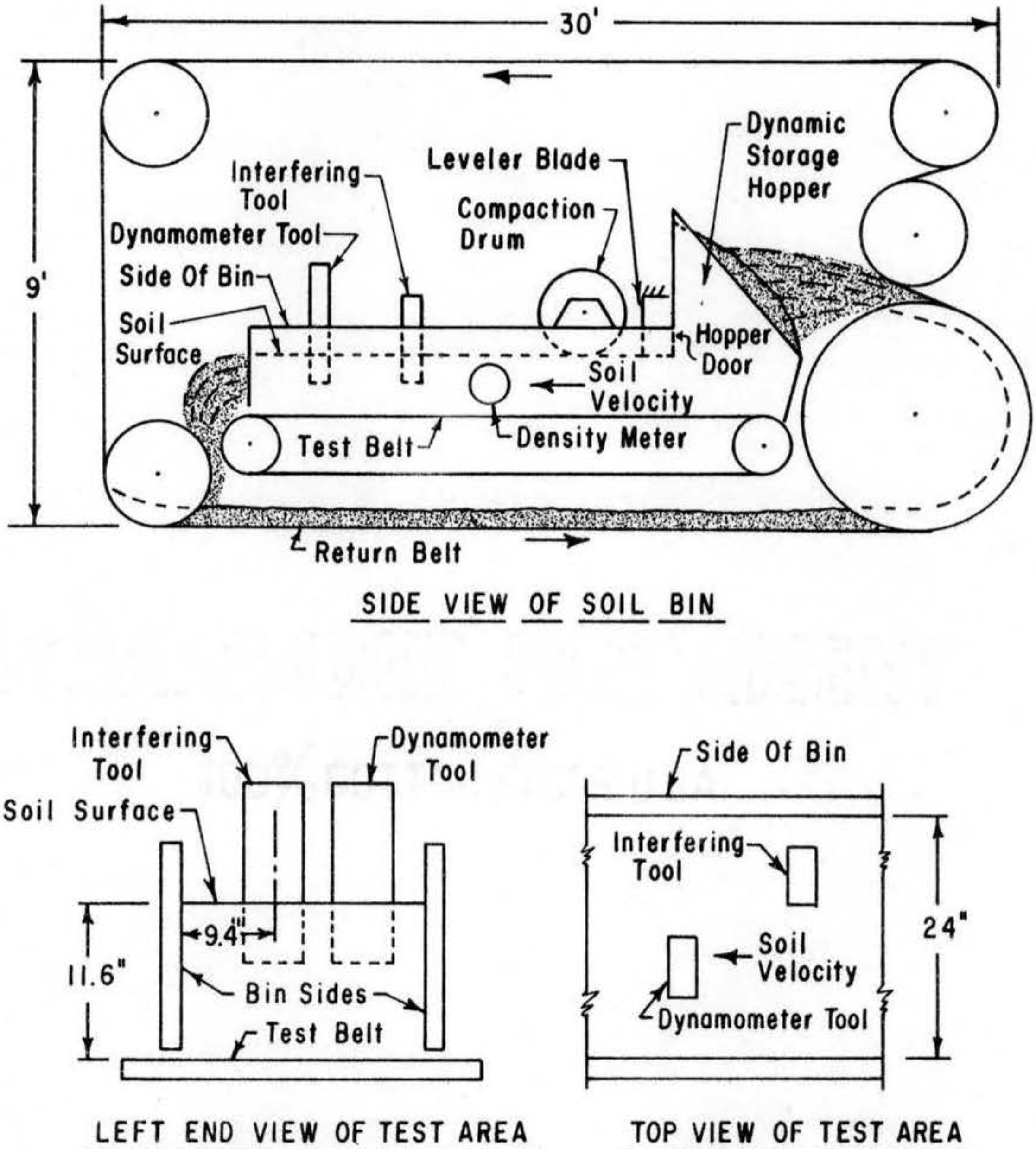


Figure 5. Schematic Diagram of Soil Bin

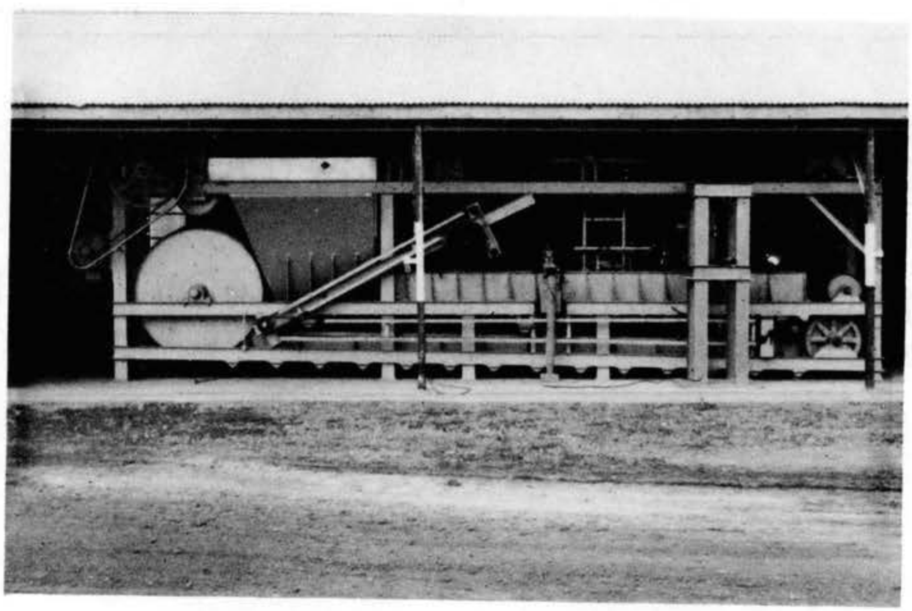


Figure 6. Soil Bin as Viewed From the South

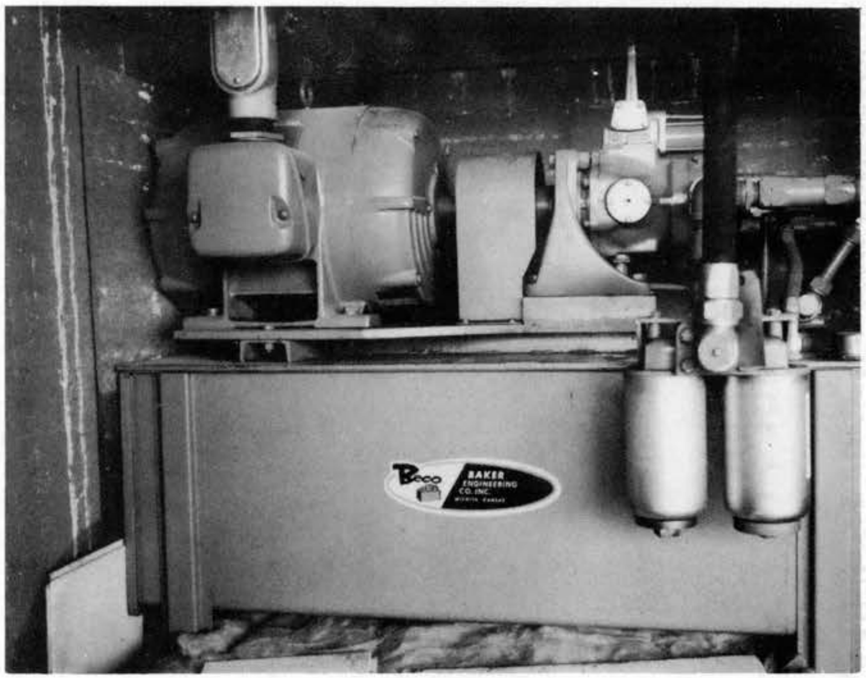


Figure 7. Unit for Supplying Hydraulic Oil Under Pressure to the Hydraulic Motor Which is Shown in Figure 8.

Figure 8. East End of the Soil Bin as Viewed From the North

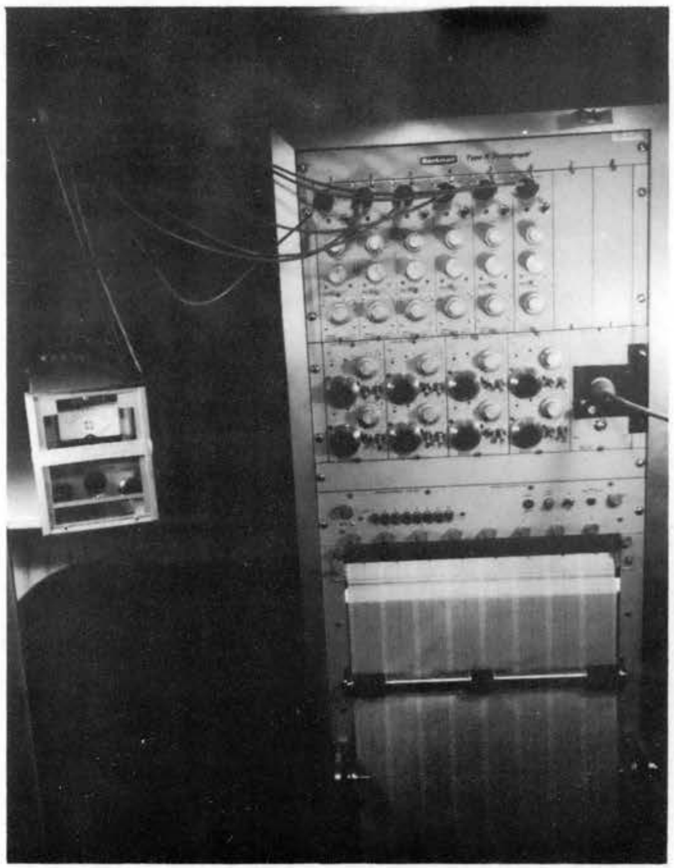


Figure 9. Density Meter and 8-Channel Recorder

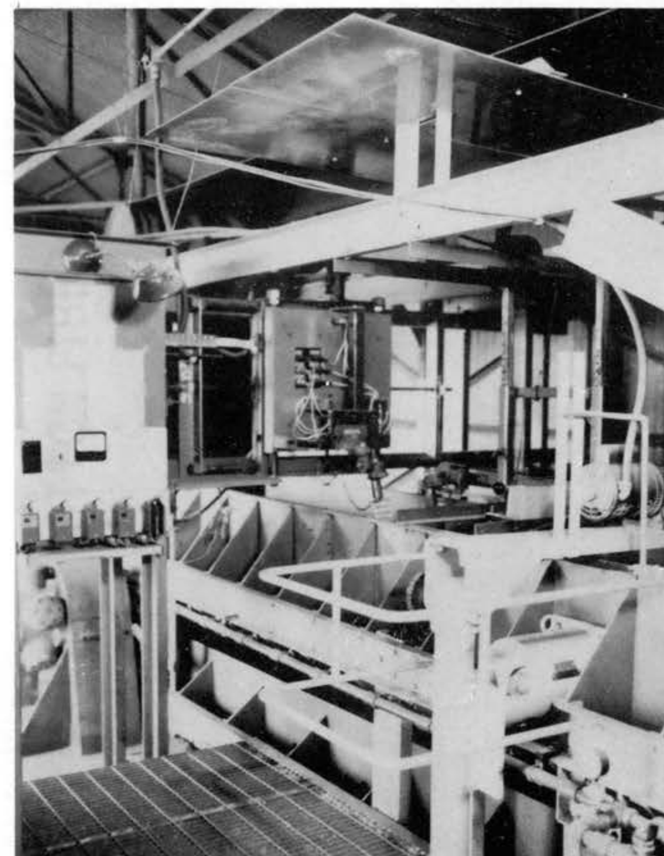


Figure 10. Central Section of the Soil Bin as Viewed From the Northwest

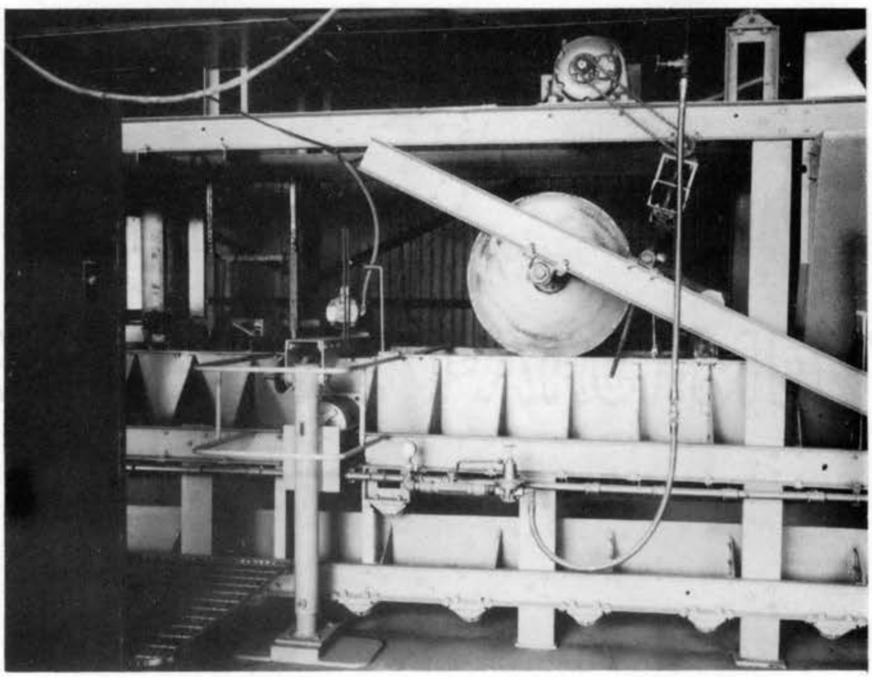


Figure 11. Central Section of the Soil Bin as Viewed From the North

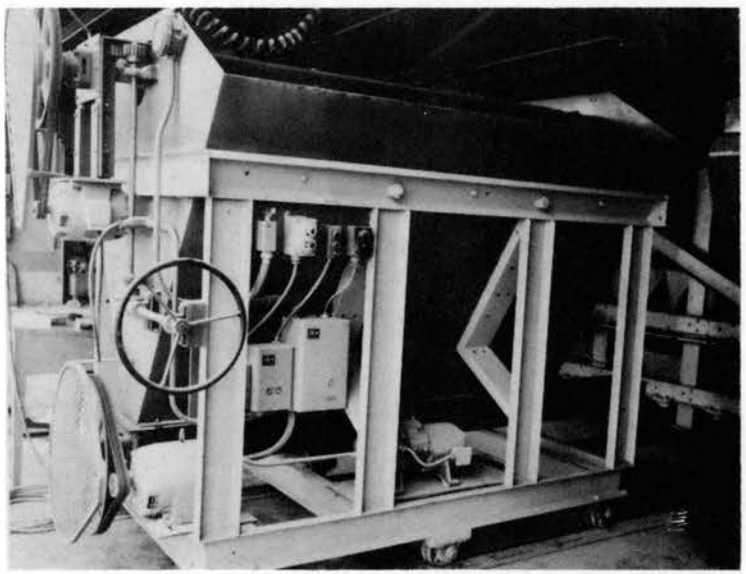


Figure 12. Static Storage Hopper for Storing the Soil When the Soil Bin is Not in Use

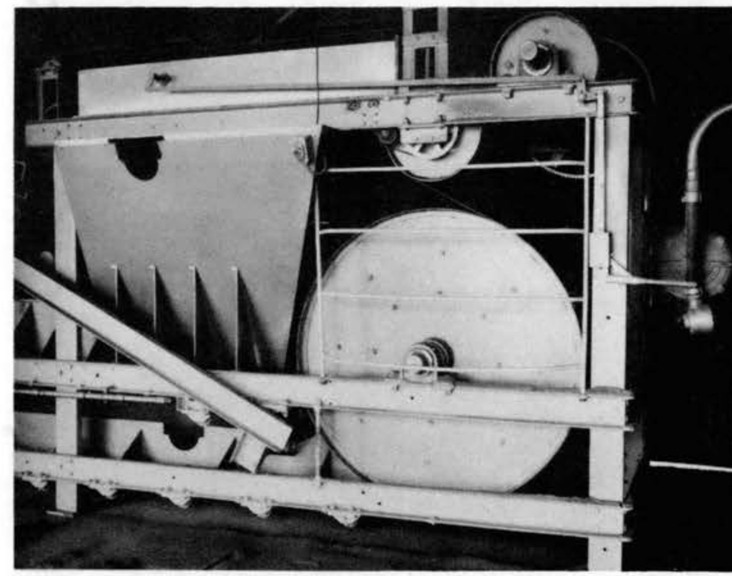


Figure 13. West End of the Soil Bin as Viewed From the North

of an 8 channel recorder. The recorder is shown in Figure 9. The two remaining channels of the recorder are used for recording soil velocity and soil density.

The test belt speed was measured by a tachometer system. A tachometer generator shaft was fitted with a disk which was allowed to roll on the test belt at a location where the test belt extended out beneath the side of the bin. The tachometer generator produced a DC voltage which was directly proportional to speed of the generator shaft. The generator produced a voltage of 7 volts per 1000 rpm of the generator shaft. Knowing the voltage per 1000 rpm and the diameter of the generator disk, the belt speed could be related to the voltage produced by the generator. The tachometer system was checked by painting dots along the test belt spaced 1 foot apart. The test belt was then operated without soil, and its linear speed was measured using a stroboscope. The belt speed as indicated by the voltage output of the generator could thus be checked against the belt speed as indicated by the stroboscope. After completing this check, a tachometer voltmeter and channel 7 of the recorder were set to read directly in feet per second. The technical specifications of the tachometer system and the recorder are given in Appendix A.

The soil density in the test section was measured with a gamma radiation instrument. With this device, the radioactive source was positioned on one side of the test bin, and the detector unit was positioned on the opposite side of the test bin. When the density device was operating, the gamma rays traveled from the source, through the soil, to the detector. The soil absorbed part of the radiation, and the portion of the radiation which reached the detector was an index of the soil density. An electrical signal traveled from the detector, was conditioned and was then available as a direct measure of soil density, once the density measurement system had been calibrated. The conditioned signal was available both on a meter, as well as on channel 8 of the recorder. Before using the density measurement system, it had to be calibrated in order to produce a signal directly related to soil density. The calibration was accomplished using the setup shown in Figure 14. The soil box could be filled with soil compacted to a particular density and the required readings taken on the density meter. The soil box could then be weighed to determine the density of the soil which it contained. The soil box was 2 feet long, the same as the width of the soil bin, and its ends were 1/4-inch thick steel plate, the same thickness as the sides of the bin in the test section. The readings taken from the density meter could thus be related to the density of the soil as determined by weighing. The technical specifications of the density measurement system are given in Appendix A.

As discussed previously, it had originally been planned that the soil on the test belt would be compacted before reaching the test section. The compaction roller intended for this purpose is shown in Figure 11. However, the principal use made of the roller in connection with this experimental program was to form a grid on the soil surface for use in taking pictures of tillage tests. The roller is shown in Figure 15 as it was used for forming the grid on the soil surface. For this application, the roller was independently driven by a variable speed device. Except when pictures were being taken, the only soil fitting was done by the leveler blade which was mounted approximately

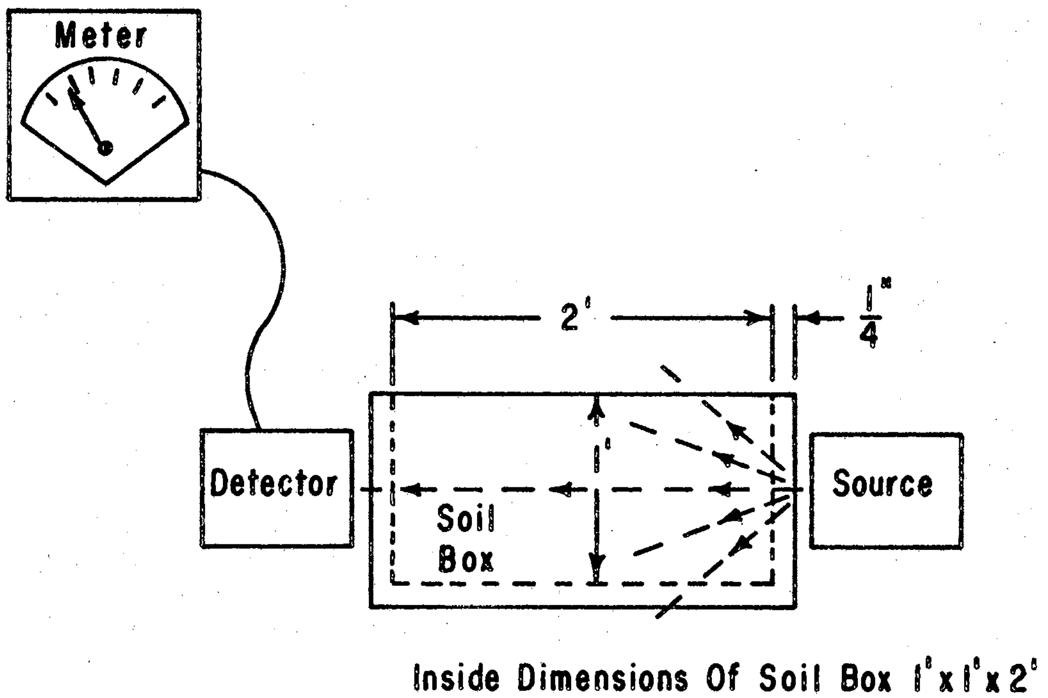


Figure 14. Set-Up for Calibration of Density Measurement System

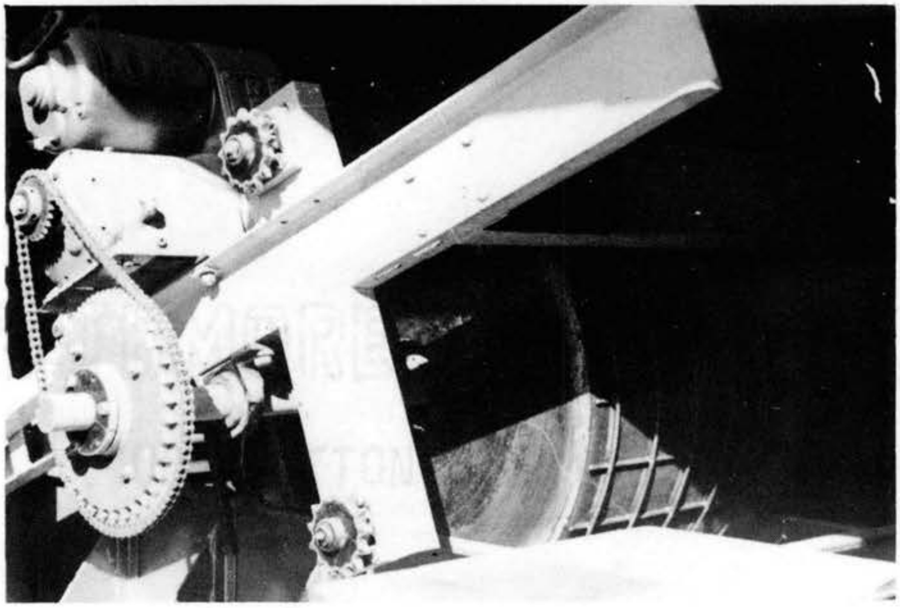


Figure 15. Compaction Drum Set-Up to Place Grid on Soil Surface for Use in Taking Pictures of Tillage Tests

2 feet from the hopper door.

The dynamometer utilized strain gage load cells in connection with the recorder. The dynamometer is shown in Figure 10. The recorder output was linear with force applied to the load cells. The calibration and linearity of the load cells were checked by loading the cells individually on a platform scale, while recording the electrical output signal on the recorder. After checking the load cells individually, they were mounted in the dynamometer and were loaded once again using test weights attached to the dynamometer. The cells were loaded together in the dynamometer to verify that the values as indicated by the test weights would be registered on the recorder. The technical specifications of the load cells are given in Appendix A. A Univise was used in connection with mounting the tillage tool on the dynamometer. The Univise allowed the tillage tool to be set at the required α and β_d angles. The dynamometer was mounted so that it could be moved up or down and from side to side.

An artificial soil mixture composed of 28.6% Ottawa flint shot white sand, 63.5% milled fire clay, and 7.9% Continental #11 spindle oil was used in these experiments. The percentages as given here are percent by weight. The artificial soil was mixed in 400 pound batches in a cement mixer. A total of 4 tons of artificial soil was mixed. The soil shear strength was determined with a direct shear device. One soil sample was taken before the start of the factorial program, and another soil sample was taken after the completion of the factorial program. In the initial sample, cohesion was 0.008 psi; the adhesion was 0.000 psi; the angle of soil-soil shear was 35.9°; and the angle of soil-metal shear was 21.5°. In the final sample, cohesion was

0.000 psi; the adhesion was 0.000 psi; the angle of soil-soil shear was 35.8°; and the angle of soil-metal shear was 22.6°.

When the soil bin was not being used, the soil was stored in the static storage hopper shown in Figure 12. When it was desired to transfer soil from the soil bin to the static storage hopper, the static storage hopper was moved along tracks until the augers extended into the soil bin. A baffle was then positioned near the top auger; the auger was turned on, and as the soil was thrown from the 5-foot diameter lift pulley, it was directed into the auger trough. The top auger then conveyed the soil to the static storage hopper. When it was desired to transfer soil from the static storage hopper to the soil bin, the bottom auger was started, and soil was deposited onto the return belt.

The return belt was powered at constant speed by a 50 horsepower electric motor. The return belt drive can be seen at the extreme left side of Figure 6. The test belt was driven by a fixed displacement hydraulic motor which can be seen in Figure 8. Hydraulic oil under pressure was supplied to the hydraulic motor by a variable displacement hydraulic pump which was connected to a 60 horsepower electric motor. The electric motor, hydraulic pump, and hydraulic reservoir are shown in Figure 7. The variable displacement feature of the hydraulic pump allowed the test belt to be operated at any speed between 0 and 8 ft/sec.

A device was constructed which allowed the interfering tool to be positioned at various depths and longitudinal locations in the soil bin. This two-dimensional movement allowed the values of y and d to be obtained. The required values of x were obtained by moving the dynamometer sideways. As with the dynamometer tool, a Univise was used in connection with the mounting of the interfering tool so that the required α and β_i angles could be set. The device for positioning the interfering tool is shown in Figure 10.

When the soil bin was first placed in operation, difficulty was encountered in operating the test belt with a depth of soil greater than 10 inches, especially if the soil was being compacted with the roller. The problem arose due to high friction between the test belt and the steel slider plate upon which it operated. An air system was devised to meter pressurized air between the belt and the slider plate. The air was supplied through 17, 1/4-inch diameter holes running longitudinally along the center of the slider plate. Thirty cubic feet per minute of air at one pound per square inch of pressure reduced the friction approximately 50 percent.

Preliminary tests were conducted to determine the size of tools that could be operated in the soil bin such that the bin sides and bottom (the belt) would not cause interference with the tools. It was found that a tool 3 inches wide and 5 inches deep could be operated within 4 inches from the bottom of the bin without measurable bottom interference occurring. Interference from the bin sides is discussed in Chapter V.

The Tillage Tools

The tillage tools were manufactured from 3/4-inch thick cold finished steel. The tools were milled to the dimensions shown in Figure 16. The front surfaces of the tools were given their final finishes with #80 sandpaper on an orbital sander. The orbital sander

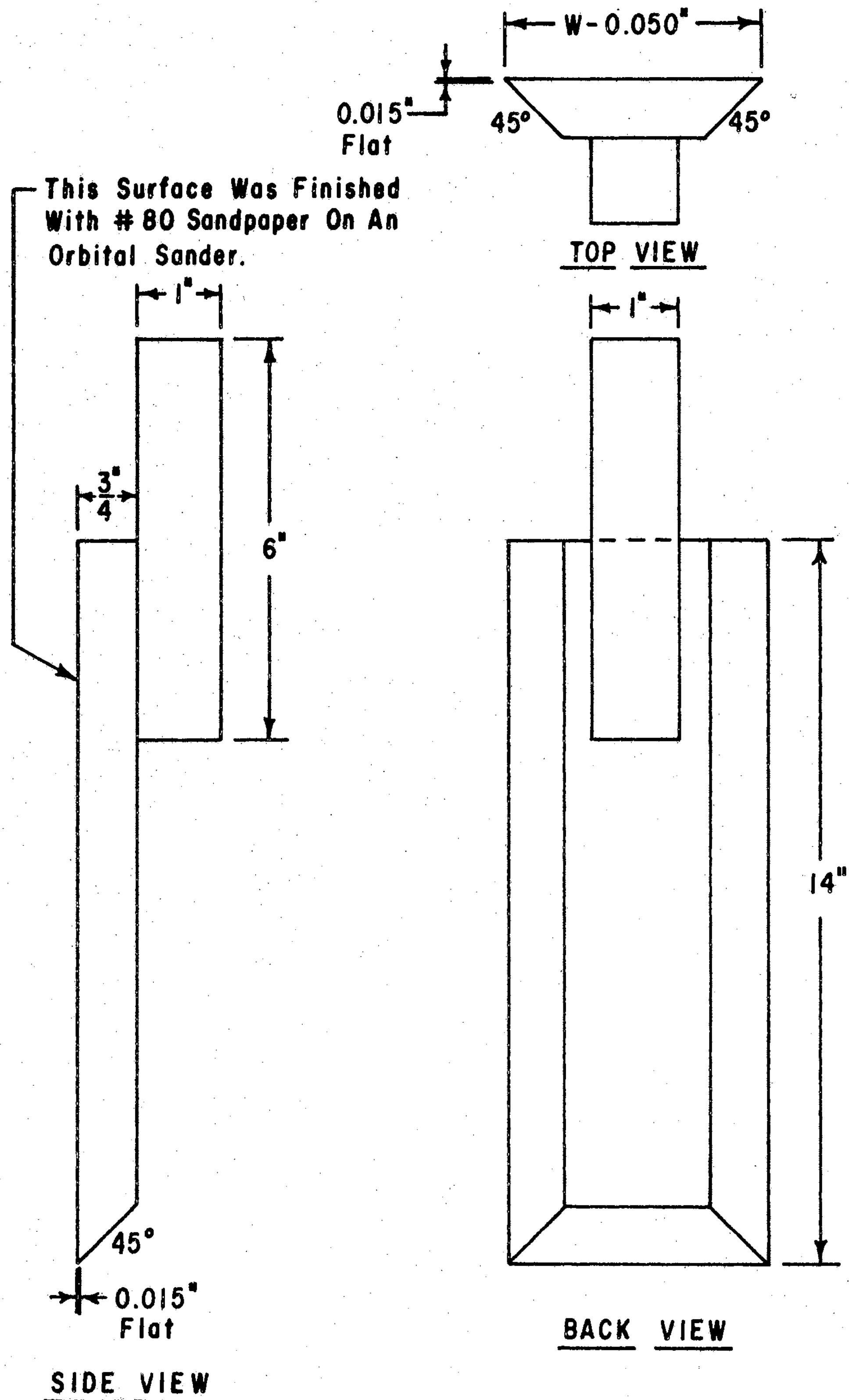


Figure 16. Tillage Tool Specifications

provided a finish with a somewhat random orientation. One 2-inch wide tool and one 4-inch wide tool were made. Three 3-inch wide tools were made. The reason for having three 3-inch wide tools was to lessen the effects of any tillage tool wear that might occur during the tests. Since the 3-inch wide tools were used as the dynamometer tool, any wear on them would affect results in a more pronounced manner than would wear on the interfering tool. However, after completion of the tests, no wear was detected on any of the tools. In order to provide structural strength and prevent significant deflection under load, 3/4-inch thick tools were used. The 45° relief on the sides and bottom of the tillage tools was designed to lessen the effects of the tools not being of zero thickness.

Procedure for Conducting Factorial Program

The following procedure was used in connection with the overall factorial experimental program.

1. Conduct 32 series: $(2V)(2w)(2\alpha)(2\beta_d)(2\beta_i) = 32$. Randomly select order of conducting series. That is, randomly determine which series will be conducted first, second, third, etc.
2. From the pool of three tools, randomly select the dynamometer tool required for a particular series.
3. Conduct 20 tests per series: $(2x)(5y)(2d) = 20$. For each series, conduct tests in a random order which has been assigned to that series only.
4. Take two observations for each test.
5. Take a soil sample before starting the factorial program.
6. Before starting program, mount each tool as dynamometer tool

and measure forces.

7. Before starting program, set instrument zero and standardization potentiometers on density meter.

8. Record standardization reading on density meter whenever test bin is empty.

9. After completing factorial program, mount each tool as dynamometer tool and measure forces.

10. Take a soil sample after completing all tests.

Procedure for Conducting Each Series

The following procedure was used in connection with each series.

1. Record instrument zero reading on density meter.
2. Install tools in required orientations.
3. Zero recorder.
4. Bring soil up to required speed.

   Zero soil depth with respect to interfering tool.

   Check soil depth in dynamic storage hopper.

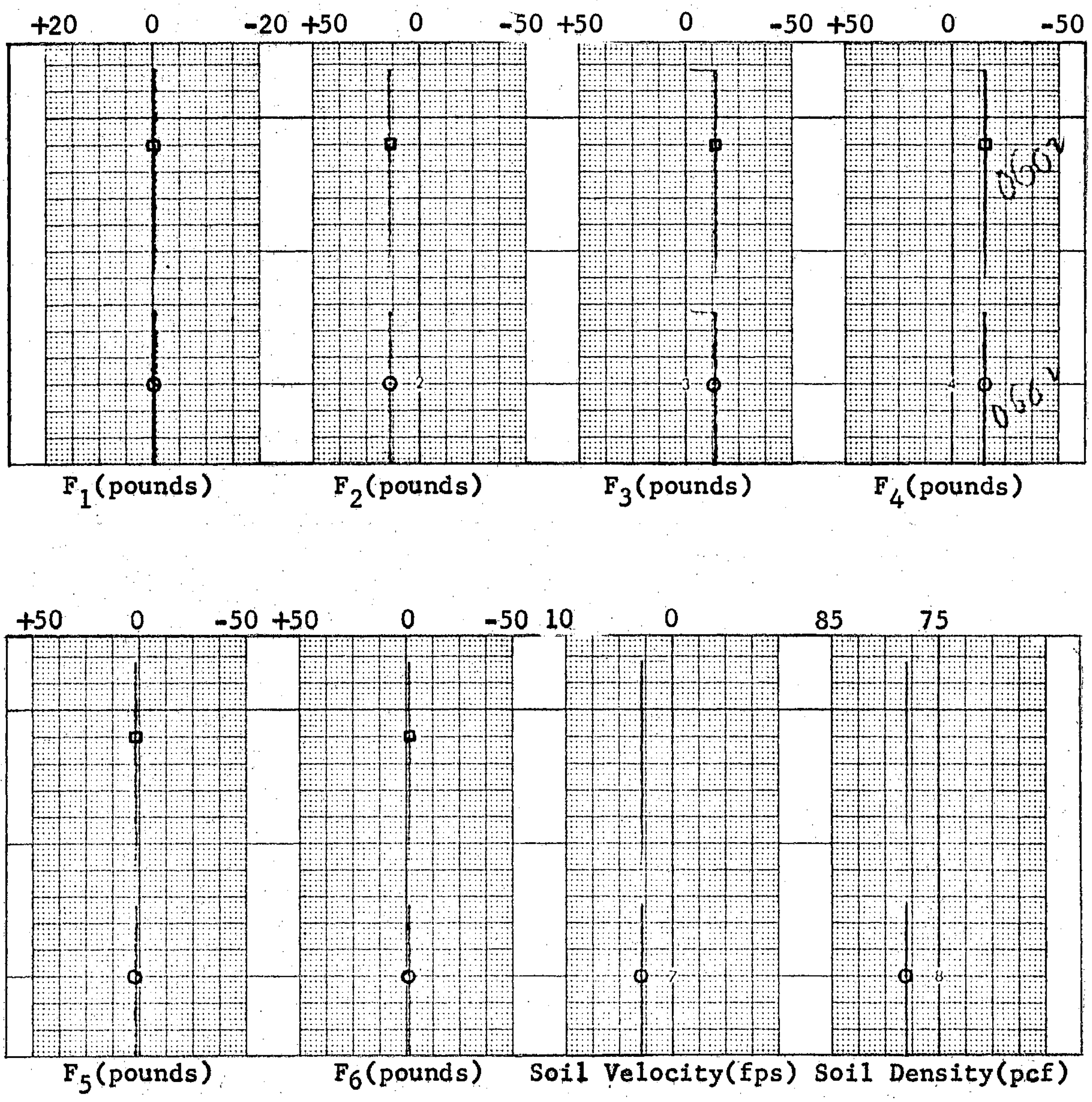
   Position soil depth gage.
5. Zero dynamometer tool and its depth scale.
6. Put dynamometer tool into soil, and do not change depth of dynamometer tool for entire series.
7. Record at 1 cm/sec without interfering tool in soil.
8. For each test, position interfering tool, visually check soil depth, then check-off test and record at 1 cm/sec.

   Note: For a test in which y = -15" is required, record without interfering tool in soil, since y = -15" represents a reference condition in which the interfering tool would be so far behind the dynamometer tool, that it would not influence the forces on the dynamometer tool.

9. For second observation, look at data sheet to see what position of interfering tool is required, see that tool is correctly positioned, observe that the soil depth has not changed, put a second check on data sheet, and then record at 1 cm/sec.
10. After completing all tests in the series, record at 1 cm/sec without interfering tool in the soil.
11. Position tools at their zero depths, and check for change in soil depth.
12. Check recorder zero.
13. Record instrument zero reading on density meter.

Recording of Data

A recorder chart sample is shown in Figure 17, and a sample data sheet is shown in Figure 18. The values read from the recorder chart were written on the data sheet in the row identified by the arrow (Test 0602). The recorder chart was 8 channels wide (the chart was cut in two for convenience in mounting), and the channels were identified by numbers printed on the chart. In operation of the recorder, the chart moved downward, and the styluses moved only from side to side. The load cell forces were recorded on channels 1 thru 6. The soil velocity was recorded on channel 7, and the soil density was recorded on channel 8. The locations of the load cell forces on the dynamometer T are given in Figure 2. On the chart and on the data sheet, forces had a positive sign when the load cells were in tension and had a negative sign when the load cells were in compression. The data was



Notes: Circles indicate observation #1
Squares indicate observation #2

Figure 17. Sample of Recorder Chart

AN INVESTIGATION OF INTERFERENCE BETWEEN TWO FLAT PLATE TILLAGE TOOLS

Researcher's Name: Tom S. Chisholm
Department: Agri. Engr. (O.S.U.)
Width of Dynamometer Tool: W = 3"
Depth of Dynamometer Tool: D = 5"
Soil Density Meas. 5 3/8" Below Surface
Soil Depth: 11 5/8" Above Test Belt
Time of Run: 10-8-69; 3:30 P to 4:45 P

Series #06
Soil Velocity: 3 fps
Width of Int. Tool: w = 4"
Rake Angle of Tools: $\alpha = 75^o$
Side Angle of Dyn. Tool: $\beta_d = 75^o$
Side Angle of Int. Tool: $\beta_i = 105^o$
Tool #2

	Position of Int. Tool			Density	Velocity	F_1, Side		F_2, Top Draft		F_3, North Draft		F_4, South Draft		F_5, North Vert.		F_6, South Vert.	
Test No.	x	y	d	ρ	V	Obs. #1	Obs. #2	Obs. #1	Obs. #2	Obs. #1	Obs. #2	Obs. #1	Obs. #2	Obs. #1	Obs. #2	Obs. #1	Obs. #2
	inches	inches	inches	lb/ft^3	ft/sec	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb
Zero Set				78.9		0.0		0.0		0.0		0.0		0.0		0.0	
Initial Standard				78.0	3.0	-3.0	-3.0	17.5	18.0	-21.0	-21.5	-16.5	-17.0	- 4.0	- 4.0	3.5	3.5
0 601	2.5	- 4	4	78.0	3.0	-5.0	-5.0	21.0	21.0	-25.5	-25.5	-18.5	-19.0	- 7.5	- 7.5	5.5	5.5
→ 0 602	5.5	+ 8	6	78.0	3.0	-0.4	-0.3	13.8	14.0	-13.8	-14.0	-15.0	-15.0	1.5	1.5	-1.3	-1.5
0 603	2.5	+ 8	6	78.0	3.0	-0.2	-0.2	8.0	8.0	- 8.0	- 8.0	- 9.5	- 9.5	1.5	1.5	-1.5	-1.5
0 604	2.5	+ 8	4	78.0	3.0	-1.5	-1.5	12.0	12.0	-13.5	-14.0	-12.5	-12.5	- 1.0	- 1.0	0.5	0.5
0 605	2.5	+15	4	78.0	3.0	-2.3	-2.3	14.5	14.5	-17.5	-17.5	-15.0	-15.0	- 2.5	- 2.5	1.5	1.5
0 606	5.5	+ 4	6	78.0	3.0	-0.5	-0.5	14.0	14.0	-15.0	-15.0	-16.0	-16.0	1.5	1.5	-1.0	-1.3
0 607	5.5	- 4	6	78.0	3.0	-7.2	-7.5	24.5	24.5	-33.0	-33.0	-22.0	-22.0	-11.5	-11.5	8.5	8.5
0 608	5.5	-15	6	78.0	3.0	-3.3	-3.3	17.5	17.5	-21.5	-21.5	-17.5	-17.5	- 4.0	- 4.0	2.5	2.5
0 609	5.5	-15	4	78.0	3.0	-3.3	-3.3	17.5	17.5	-22.0	-22.0	-17.5	-17.5	- 4.0	- 4.0	2.5	2.5
0 610	5.5	+15	4	78.0	3.0	-2.4	-2.4	16.5	16.5	-19.5	-19.5	-17.5	-17.5	- 2.5	- 2.5	1.0	1.0
0 611	2.5	-15	4	78.0	3.0	-3.5	-3.5	17.5	17.5	-21.5	-21.5	-17.5	-17.5	- 4.5	- 4.5	3.5	3.0
0 612	5.5	- 4	4	78.0	3.0	-5.5	-5.5	23.5	23.0	-30.0	-29.0	-21.5	-21.5	- 8.5	- 8.5	6.0	6.0
0 613	5.5	+ 8	4	78.0	3.0	-1.5	-1.5	15.5	15.5	-17.5	-17.5	-16.5	-16.5	- 1.0	- 1.0	0.0	0.0
0 614	5.5	+ 4	4	78.0	3.0	-1.0	-1.0	15.5	15.5	-17.0	-16.5	-17.0	-16.5	0.5	0.5	-0.5	-0.5
0 615	2.5	+ 4	6	78.0	3.0	-0.2	-0.2	5.0	5.0	- 5.0	- 5.0	- 6.0	- 6.5	1.5	1.5	-1.0	-1.5
0 616	5.5	+15	6	78.0	3.0	-1.7	-1.7	15.5	15.5	-17.5	-17.5	-16.5	-16.5	- 1.5	- 1.5	0.5	0.5
0 617	2.5	+ 4	4	78.0	3.0	-0.5	-0.5	8.5	8.5	- 9.0	- 9.0	-10.0	-10.0	1.0	1.0	-1.0	-1.0
0 618	2.5	- 4	6	78.0	3.0	-6.5	-6.7	21.5	21.5	-29.0	-29.0	-19.5	-19.5	-11.0	-11.0	7.5	7.5
0 619	2.5	-15	6	78.0	3.0	-3.4	-3.4	17.5	17.5	-21.5	-21.0	-17.0	-16.5	- 4.5	- 4.5	3.0	3.0
0 620	2.5	+15	6	78.0	3.0	-2.0	-2.0	12.0	12.0	-14.0	-14.0	-12.0	-12.0	- 2.0	- 2.0	1.0	1.0
Final Standard				78.0	3.0	-3.5	-3.5	18.0	18.0	-21.5	-21.5	-17.0	-17.0	- 4.5	- 4.5	3.5	3.5
Zero Check				78.0		0.5		0.0		0.5		0.5		0.5		0.2	

Instrument Zero Reading on Density Meter: Initial -0.05, Final 0.00

Figure 18. Sample Data Sheet

also punched on the data cards with this sign convention, but after being read into the computer, the signs were changed to agree with Figure 2 before calculations were made. A computer printout of the original data from the factorial program is contained in Appendix B. Load cell #1 (F_1) had a rated capacity of $\pm$ 50 pounds, and the recorder was set to indicate $\pm$ 20 pounds full scale on the chart. Load cells #2, 3, 4, 5, and 6 had rated capacities of $\pm$ 100 pounds, $\pm$ 200 pounds, $\pm$ 200 pounds, $\pm$ 100 pounds and $\pm$ 50 pounds, respectively. The recorder channels associated with these load cells were set to indicate $\pm$ 50 pounds full scale. The soil velocity channel was set to indicate 0 to 10 feet per second. The soil density channel was set to record densities in the range 75 to 85 pounds per cubic foot. The principal reason for recording soil velocity and soil density was to verify that the values of these quantities did not change appreciably from their intended values. On the recorder chart, the circles indicate observation #1, and the squares indicate observation #2. Only one observation of soil velocity and soil density was made for each test. When a test was being conducted, the recorder chart was put into operation such that traces at least 1 inch long were obtained. In reading values from the chart, the last major division (5 millimeters) line crossed by any trace was noted. The observation was then taken two major divisions back from this line. The values of the independent quantities and other information pertinent to a series were available on the data sheet. Referring to the data sheet, the zero set traces were recorded on the chart before the dynamometer tool was put into the soil. The zero check traces were recorded on the chart after the dynamometer tool had been removed from the soil. For each of the load cell forces in the body of the series, an average of the zero set and zero check values was applied as a correction. The initial standard and final standard values were recorded with the dynamometer tool in the soil by itself, without the interfering tool being in the soil. These standard values were intended to help detect unplanned changes which might occur in the system.

CHAPTER V

PRESENTATION AND DISCUSSION OF RESULTS

Presentation of Results

The raw data from the experimental program were the values of the independent variables as listed on the data sheets and the recorder chart traces of the six load cell forces. The values of the load cell forces were read from the charts, recorded on the data sheets, and then punched on data cards along with values of the independent variables. The dependent quantities (F_x, F_y, F_z, F, C_x, C_y, C_z, C, TX, and TZ) were then calculated from the load cell forces. Some of these dependent quantities could be considered as redundant. However, they were all considered so that the relationships between the independent variables and each of these dependent variables could be studied. The data in terms of the independent and dependent quantities was analyzed by partitioning sum of squares, conducting F tests on mean squares, developing prediction equations using stepwise multiple regression, and by plotting graphs involving selected interference conditions. In addition, photographs were taken of the tillage tools operating in several different interference conditions. These pictures were intended as data, in that they help to characterize interference relationships.

The means and standard deviations of the dependent factors are given in Table I.

The sum of squares partitionings and F tests are presented in Tables II thru XI. A summary of sum of squares partitionings is given in Table XII.

The prediction equations are shown in Tables XIII and XIV.

Graphs involving selected interference conditions are presented in Figures 19 thru 28.

Photographs of selected tillage tool tests are presented in Figures 29 thru 41.

Photographs of bin side interference tests are shown in Figure 42.

Photographs of soil bodies which formed on tillage tools are shown in Figures 43, 44, and 45.

TABLE I

MEANS AND STANDARD DEVIATIONS OF DEPENDENT FACTORS

Dependent Factor	Mean	Standard Deviation
F_x	- 0.123 lbs.	2.940 lbs.
F_y	20.194 lbs.	6.077 lbs.
F_z	- 4.107 lbs.	3.995 lbs.
F	21.013 lbs.	6.644 lbs.
C_x	- 0.278 in-lb	1.916 in-lb
C_y	-11.519 in-lb	6.777 in-lb
C_z	1.896 in-lb	2.156 in-lb
C	-11.908 in-lb	6.984 in-lb
TX	0.323 in.	0.227 in.
TZ	2.742 in.	0.887 in.

TABLE II

ANALYSIS OF VARIANCE FOR F_x

Source of Variation	df	Sum of Squares: Numerical Value	% of Total	Cum. % of Total	MS	F
β_d	1	7576.7	68.23	68.23	7576.7	5121.8**
y	4	2615.2	23.55	91.78	653.8	9181.3**
wy	4	169.1	1.52	93.30	42.3	594.0**
dy	4	150.7	1.36	94.66	37.7	529.4**
$\beta_d y$	4	112.5	1.01	95.67	28.1	394.6**
αy	4	110.3	0.99	96.66	27.6	387.6**
$\alpha\beta_d$	1	30.1	0.27	96.93	30.1	20.4**
Vy	4	24.1	0.22	97.15	6.0	84.3**
α	1	19.3	0.17	97.32	19.3	13.0*
$V\beta_d$	1	17.1	0.15	97.47	17.1	11.6*
$\beta_d x$	1	14.1	0.13	97.60	14.1	198.0**
$\beta_d xy$	4	12.8	0.12	97.72	3.2	44.9**
wxy	4	11.6	0.10	97.82	2.9	40.7**
wdy	4	11.4	0.10	97.92	2.8	39.3**
V	1	10.2	0.09	98.01	10.2	6.9*
Error #2	6	8.9	0.08	98.09	1.4800	
Error #4	1094	77.9	0.70	98.79	0.07121	
Sampling Error	640	27.0	0.24		0.042	
Total	1279	11,104.8				

Notes: 1. Error #2 is a pooled error term made up of the 4 and 5 factor interactions which do not contain x, y, or d. Error #2 is used for significance testing of 1, 2, and 3 factor terms which do not contain x, y, or d.

2. Error #4 is a pooled error term made up of 4, 5, 6, 7, and 8 factor interactions which do involve x, y, or d and also contains sampling error. Error #4 is used for significance testing of 1, 2, and 3 factor terms which do involve x, y, or d.

3. Significance of F values at the 1% level indicated by **. Significance at the 5% level indicated by *. Lack of significance at the 5% level indicated by N.S.

TABLE III

ANALYSIS OF VARIANCE FOR F_y

Source of Variation	df	Sum of Squares: Numerical Value	% of Total	Cum. % of Total	MS	F
y	4	20501.3	43.38	43.38	5125.3	14350.8**
α	1	14540.1	30.76	74.14	14540.1	747.4**
x	1	2203.8	4.66	78.80	2203.8	6170.6**
xy	4	1703.6	3.60	82.40	425.9	1192.5**
wy	4	1284.7	2.71	85.11	321.2	899.4**
dy	4	1267.3	2.68	87.79	316.8	887.0**
V	1	1265.1	2.67	90.46	1265.1	65.0**
αy	4	1078.1	2.28	92.74	269.5	754.6**
β_{dy}	4	474.3	1.00	93.74	118.6	332.1**
d	1	337.0	0.71	94.45	337.0	943.6**
wx	1	245.6	0.51	94.96	245.6	687.7**
Vy	4	242.4	0.51	95.47	60.6	169.7**
Vx	1	179.3	0.37	95.84	179.3	502.0**
w	1	128.3	0.27	96.11	128.3	6.6*
αdy	4	98.2	0.20	96.31	24.5	68.6**
Error #2	6	114.3	0.24	96.55	19.046	
Error #4	1094	391.1	0.82	97.37	0.35752	
Sampling Error	640	78.7	0.16		0.123	
Total	1279	47,258.9				

Notes: Refer to Table II for notes.

TABLE IV

ANALYSIS OF VARIANCE FOR F_z

Source of Variation	df	Sum of Squares: Numerical Value	Sum of Squares: % of Total	Sum of Squares: Cum. % of Total	MS	F
α	1	16072.0	78.81	78.81	16072.0	2346.5**
y	4	1917.1	9.40	88.21	479.3	1993.9**
αy	4	831.4	4.07	92.28	207.9	864.8**
dy	4	227.7	1.11	93.39	56.9	236.7**
β_{dy}	4	152.6	0.74	94.13	38.1	158.5**
wy	4	115.8	0.56	94.69	28.9	120.2**
xy	4	95.4	0.46	95.15	23.9	99.4**
αdy	4	71.7	0.35	95.50	17.9	74.5**
d	1	59.9	0.29	95.79	59.9	249.2**
αxy	4	49.1	0.24	96.03	12.3	51.2**
αd	1	43.4	0.21	96.24	43.4	180.5**
x	1	41.6	0.20	96.44	41.6	6.1*
wαy	4	41.0	0.20	96.64	10.2	42.4**
αx	1	32.1	0.15	96.79	32.1	133.5**
V	1	23.3	0.11	96.90	23.3	3.4N.S.
Error #2	6	41.2	0.20	97.10	6.8588	
Error #4	1094	262.8	1.28	98.38	0.24020	
Sampling Error	640	45.7	0.22		0.071	
Total	1279	20,392.8				

Notes: Refer to Table II for notes.

TABLE V

ANALYSIS OF VARIANCE FOR F

Source of Variation	df	Sum of Squares: Numerical Value	% of Total	Cum. % of Total	MS	F
y	4	22446.8	39.74	39.74	5611.7	14253.7**
α	1	20272.3	35.89	75.63	20272.3	10136.6**
x	1	2208.3	3.90	79.53	2208.3	5609.1**
xy	4	1761.1	3.11	82.64	440.3	1118.4**
αy	4	1500.4	2.65	85.29	375.1	952.8**
dy	4	1454.9	2.57	87.86	363.7	923.8**
wy	4	1442.2	2.55	90.41	360.5	915.7**
V	1	1287.3	2.27	92.68	1287.3	64.4**
$\beta_d y$	4	858.1	1.51	94.19	214.5	544.8**
d	1	353.7	0.62	94.81	353.7	898.4**
Vy	4	249.1	0.44	95.25	62.3	158.2**
wx	1	245.5	0.43	95.68	245.5	623.6**
Vx	1	192.9	0.34	96.02	192.9	490.0**
$\alpha_d y$	4	150.9	0.26	96.28	37.7	95.8**
w	1	105.4	0.18	96.46	105.4	5.27N.S.
Error #2	6	122.1	0.22	96.68	20.344	
Error #4	1094	430.6	0.76	97.44	0.39360	
Sampling Error	640	78.0	0.13		0.12	
Total	1279	56,480.8				

Notes: Refer to Table II for notes.

TABLE VI

ANALYSIS OF VARIANCE FOR C_x

Source of Variation	df	Sum of Squares Numerical Value	% of Total	Cum. % of Total	MS	F
β_d	1	2442.95	49.89	49.89	2442.95	415.3**
y	4	825.94	16.86	66.75	206.48	363.4**
β_{dy}	4	135.95	2.77	69.52	33.99	59.8**
$\alpha\beta_d$	1	114.89	2.34	71.86	114.89	19.5**
wy	4	80.39	1.64	73.50	20.10	35.4**
dy	4	55.22	1.12	74.62	13.81	24.3**
V	1	53.46	1.09	75.71	53.46	9.1*
$V\beta_d\beta_i$	1	45.06	0.92	76.63	45.06	7.7*
$Vw\alpha$	1	44.25	0.90	77.53	44.25	7.5*
$V\alpha\beta_d$	1	39.68	0.81	78.34	39.68	6.8*
$w\beta_d$	1	38.81	0.79	79.13	38.81	6.6*
$w\alpha\beta_i$	1	27.55	0.56	79.69	27.55	4.7N.S.
αy	4	26.95	0.55	80.24	6.74	11.9**
$Vw\alpha\beta_{dy}$	4	24.95	0.50	80.74	6.24	
w	1	23.27	0.47	81.21	23.27	4.0N.S.
Error #2	6	34.83	0.71	81.92	5.8043	
Error #4	1094	622.78	12.71	94.63	0.56927	
Sampling Error	640	213.74	4.36		0.334	
Total	1279	4896.39				

Notes: Refer to Table II for notes.

TABLE VII

ANALYSIS OF VARIANCE FOR C_y

Source of Variation	df	Sum of Squares: Numerical Value	Sum of Squares: % of Total	Sum of Squares: Cum. % of Total	MS	F
y	4	7673.3	11.37	11.37	1918.3	94.0**
β_d	1	5466.8	8.10	19.47	5466.8	
$V\beta_i$	1	3037.4	4.50	23.97	3037.4	
$V\beta_d$	1	2510.1	3.72	27.69	2510.1	
$Vw\alpha\beta_d$	1	2182.6	3.23	30.92	2182.6	
w	1	2103.1	3.11	34.03	2103.1	
$w\alpha$	1	2039.3	3.02	37.05	2039.3	
$w\beta_d$	1	2007.3	2.97	40.02	2007.3	
$V\alpha$	1	1555.1	2.30	42.32	1555.1	
$\alpha\beta_d\beta_i$	1	1456.0	2.15	44.47	1456.0	
α	1	1387.2	2.05	46.52	1387.2	
$w\alpha\beta_d\beta_i$	1	1361.7	2.01	48.53	1361.7	
$V\alpha\beta_d$	1	1320.2	1.95	50.48	1320.2	
$Vw\beta_d$	1	1228.1	1.82	52.30	1228.1	
x	1	1224.5	1.81	54.11	1224.5	60.0**
Error #4	1094	22172.5	32.86	86.97	20.267	
Sampling Error	640	8771.3	12.99		13.7	
Total	1279	67472.8				

Notes: Refer to Table II for notes.

TABLE VIII

ANALYSIS OF VARIANCE FOR C_z

Source of Variation	df	Sum of Squares: Numerical Value	% of Total	Cum. % of Total	MS	F
α	1	2760.44	43.02	43.02	2760.44	171.2**
y	4	704.76	10.98	54.00	176.19	151.5**
αy	4	218.44	3.40	57.40	54.61	47.0**
$V\alpha\beta_d$	1	201.29	3.13	60.53	201.29	12.5*
$w\alpha\beta_d$	1	129.49	1.98	62.51	127.49	7.9*
$V\beta_d$	1	123.88	1.93	64.44	123.88	7.7*
$w\beta_d$	1	91.91	1.43	65.87	91.91	5.7N.S.
$\alpha\beta_d$	1	86.17	1.34	67.21	86.17	5.3N.S.
β_d	1	80.70	1.25	68.46	80.70	5.0N.S.
$V\beta_i$	1	59.51	0.92	69.38	59.51	3.7N.S.
$\alpha\beta_d\beta_i$	1	46.97	0.73	70.11	46.97	2.9N.S.
dy	4	44.40	0.69	70.80	11.10	9.6**
$\beta_d y$	4	41.77	0.65	71.45	10.44	9.0**
xy	4	37.60	0.58	72.03	9.40	8.1**
$Vw\alpha\beta_d\beta_i$	1	30.85	0.48	72.51	30.85	
Error #2	6	96.49	1.50	74.01	16.081	
Error #4	1094	1267.97	19.76	93.77	1.1590	
Sampling Error	640	473.24	7.37		0.74	
Total	1279	6416.99				

Notes: Refer to Table II for notes.

TABLE IX

ANALYSIS OF VARIANCE FOR C

Source of Variation	df	Sum of Squares Numerical Value	% of Total	Cum. % of Total	MS	F
y	4	8522.1	11.87	11.87	2130.5	97.53**
β_d	1	5787.1	8.06	19.93	5787.1	
$V\beta_i$	1	3213.7	4.47	24.40	3213.7	
$V\beta_d$	1	2763.2	3.84	28.24	2763.2	
$Vw\alpha\beta_d$	1	2281.9	3.17	31.41	2281.9	
w	1	2227.4	3.10	34.51	2227.4	
$w\beta_d$	1	2189.0	3.04	37.55	2189.0	
$w\alpha$	1	2062.1	2.87	40.42	2062.1	
$V\alpha$	1	1611.6	2.24	42.66	1611.6	
$\alpha\beta_d\beta_i$	1	1550.1	2.15	44.81	1550.1	
$V\alpha\beta_d$	1	1483.8	2.06	46.87	1483.8	
$w\alpha\beta_d\beta_i$	1	1455.7	2.02	48.89	1455.7	
x	1	1250.5	1.74	50.63	1250.5	57.25**
$Vw\beta_d$	1	1238.3	1.72	52.35	1238.3	
V	1	1012.0	1.40	53.75	1012.0	
Error #4	1094	23894.0	33.28	87.03	21.8410	
Sampling Error	640	9434.8	13.14		14.7	
Total	1279	71794.4				

Notes: Refer to Table II for notes.

TABLE X

ANALYSIS OF VARIANCE FOR TX

Source of Variation	df	Sum of Squares: Numerical Value	% of Total	Cum. % of Total	MS	F
y	4	9.752	13.23	13.23	2.438	99.8**
α	1	6.088	8.26	21.49	6.088	
$w\alpha$	1	2.980	4.04	25.53	2.980	
$V\alpha\beta_d\beta_i$	1	2.075	2.82	28.35	2.075	
$w\alpha\beta_d\beta_i$	1	1.928	2.61	30.96	1.928	
V	1	1.905	2.57	33.53	1.905	
$V\beta_i$	1	1.847	2.51	36.04	1.847	
$V\beta_d$	1	1.432	1.94	37.98	1.432	
w	1	1.367	1.85	39.83	1.367	
$\alpha\beta_d\beta_i$	1	1.305	1.77	41.60	1.305	
xy	4	1.161	1.57	43.17	0.290	11.9**
αy	4	1.138	1.54	44.71	0.284	11.6**
$Vw\beta_d$	1	1.057	1.42	46.13	1.057	
$Vw\beta_i$	1	0.978	1.33	47.46	0.978	
dy	4	0.868	1.22	48.68	0.217	8.9**
Error #4	1094	26.727	36.28	84.96	0.02443	
Sampling Error	640	8.112	11.00		0.013	
Total	1279	73.667				

Notes: Refer to Table II for notes.

TABLE XI

ANALYSIS OF VARIANCE FOR TZ

Source of Variation	df	Sum of Squares Numerical Value	% of Total	Cum. % of Total	MS	F
$Vw\beta_d\beta_i$	1	112.81	9.87	9.87	112.81	
V	1	77.26	6.76	16.63	77.26	
$Vw\beta_i$	1	54.70	4.78	21.41	54.70	
$\alpha\beta_d$	1	39.20	3.43	24.84	39.20	
$w\beta_d\beta_i$	1	28.94	2.53	27.37	28.94	
$w\alpha\beta_d\beta_i$	1	28.71	2.51	29.88	28.71	
$V\alpha$	1	22.48	1.96	31.84	22.48	
w	1	21.62	1.89	33.73	21.62	
y	4	21.32	1.86	35.59	5.33	13.0**
β_d	1	21.11	1.84	37.43	21.11	
$\beta_d\beta_i$	1	20.94	1.83	39.26	20.94	
$w\alpha\beta_d$	1	17.81	1.55	40.81	17.81	
$w\beta_i$	1	16.94	1.48	42.29	16.94	
$V\alpha\beta_d\beta_i$	1	16.51	1.44	43.73	16.51	
$w\alpha\beta_i dy$	4	15.42	1.34	45.07	3.85	
Error #4	1094	449.30	39.33	84.40	0.41070	
Sampling Error	640	135.42	11.85		0.21	
Total	1279	1142.25				

Notes: Refer to Table II for notes.

TABLE XII

SUM OF SQUARES PARTITIONINGS

Source of Variation	F_x	F_y	F_z	F	C_x	C_y	C_z	C	TX	TZ	Average
α	0.17	30.76	78.81	35.89		2.05	43.02		8.26		19.90
y	23.55	43.38	9.40	39.74	16.86	11.37	10.98	11.87	13.23	1.86	18.22
β_d	68.23				49.89	8.10	1.25	8.06	1.84		13.74
V	0.09	2.67	0.11	2.27	1.09			1.40	2.57	6.76	1.70
αy	0.99	2.28	4.07	2.65	0.55		3.40		1.54		1.55
$V\beta_i$						4.50	0.92	4.47	2.51		1.24
x		4.66	0.20	3.90		1.81		1.74			1.23
$V\beta_d$	0.15					3.72	1.93	3.84	1.94		1.16
w		0.27		0.18	0.47	3.11		3.10	1.85	1.89	1.09
$_{d}y$	1.36	2.68	1.11	2.55	1.12		0.69		1.22		1.07
$Vw\beta_d\beta_i$										9.87	0.99
$w\alpha$						3.02		2.87	4.04		0.99
xy		3.60	0.46	3.11			0.58		1.57		0.93
$w\alpha\beta_d\beta_i$						2.01		2.02	2.61	2.51	0.92
wy	1.52	2.71	0.56	2.55	1.64						0.90
$w\beta_d$					0.79	2.97	1.43	3.04			0.82
$V\alpha\beta_d$					0.81	1.95	3.13	2.06			0.80
$\beta_d y$	1.01	1.00	0.74	1.51	2.77		0.65				0.77
$\alpha\beta_d$	0.27				2.34		1.34			3.43	0.74
$V\alpha$						2.30		2.24		1.96	0.65
$Vw\alpha\beta_d$						3.23		3.17			0.64
$Vw\beta_i$									1.33	4.78	0.61
$\alpha\beta_d\beta_i$						2.15	0.73	2.15			0.50
$V\alpha\beta_d\beta_i$									2.82	1.44	0.43
$w\alpha\beta_d$							1.98			1.55	0.35
$V\beta_d\beta_i$					0.92				1.77		0.27
$w\beta_d\beta_i$										2.53	0.25
$\beta_d\beta_i$										1.83	0.18
d		0.71	0.29	0.62							0.16
Vy	0.22	0.51		0.44							0.12
$Vw\alpha$					0.90						0.09
wx		0.51		0.43							0.09
αdy		0.20	0.35	0.26							0.08
αxy			0.24								0.02
αd			0.21								0.02
$\beta_d x$	0.13										0.01

Note: Tabular values are percent of total variation.

TABLE XIII

DEVELOPMENT OF PREDICTION EQUATIONS

Dependent Quantity	First Term Added			Second Term Added			Third Term Added			Fourth Term Added			Fifth Term Added			Sixth Term Added			% For Constant Plus Ten Terms
	Term	%*	F**	Term	%	F	Term	%	F	Term	%	F	Term	%	F	Term	%	F	
F_x	β_{d_1}	68.4	1378	y	73.1	865	y^3	88.1	1573										
F_x	β_{d_1}	68.4	1378	wy	73.5	883	wy^3	88.6	1645										94.0
F_y	α	30.9	285	y	40.6	218	y^3	69.4	481										
F_y	α	30.9	285	wy	41.8	229	wy^3	71.9	542	Vx	79.0	596							83.9
F_z	α	79.1	2411	y	80.2	1289	y^3	86.6	1372										
F_z	α	79.1	2411	αy	80.5	1312	αy^3	88.2	1578										93.0
F	α	35.9	358	y	44.7	257	y^3	71.3	526										
F	α	35.9	358	wy	45.7	268	wy^3	73.4	586	Vx	79.5	616							87.6
C_x	β_{d_1}	52.3	698	y	55.8	401	y^3	66.6	422										
C_x	β_{d_1}	52.3	698	wy	56.4	411	wy^3	68.4	460	$\alpha\beta_{d_1}$	70.9	386							77.7
C_y	y	3.1	20	y^3	11.6	42	α	14.0	34										
C_y	$\alpha\beta_d$	9.9	70	wx	15.3	58	Vy	18.8	49	Vy^3	26.1	56	$\beta_{d_1}\beta_i$	27.6	48	$Vw\alpha\beta_{d_1}$	34.6	56	38.3
C_z	α	46.4	553	y	48.4	299	y^3	55.9	269										
C_z	α	46.4	553	αy	49.0	305	αy^3	57.5	287	$\alpha\beta_d$	59.3	232	$Vw\alpha\beta_{d_1}$	64.0	225				66.8
C	y	3.2	21	y^3	12.1	44	α	13.5	33										
C	β_{d_1}	9.3	65	$Vw\alpha\beta_{d_1}$	16.6	63	wx	21.8	59	αy	25.5	54	αy^3	34.8	68	V	36.5	61	42.5
TX	α	9.3	65	y	11.0	39	y^3	19.3	51										
TX	α	9.3	65	V	12.2	44	w	14.2	35	$w\alpha$	18.8	37	αy	20.9	33	αy^3	29.8	45	38.0
TZ	V	7.7	53	$Vw\beta_{d_1}\beta_i$	12.7	46													
TZ	Vw	8.8	62	$Vw\beta_{d_1}\beta_i$	13.8	51	$Vw\alpha\beta_{d_1}$	22.5	62										26.8

Notes:
1. %* indicates the percent of the total variation which is accounted for by the associated equation.
2. F** is the statistical F for the associated equation. These F values are significant at the 1% level for all equations.
3. $\beta_{d_1} = \beta_d - 90^o$.

TABLE XIV

PRESENTATION OF PREDICTION EQUATIONS

$$F_x = 3.328 \times 10^{-1} - 1.619 \times 10^{-1} \beta_{d_1} - 3.923 \times 10^{-1} y + 1.677 \times 10^{-3} y^3, \ \%^* = 88.1, \ F^{**} = 1573$$

$$F_x = 3.105 \times 10^{-1} - 1.619 \times 10^{-1} \beta_{d_1} - 1.262 \times 10^{-1} wy + 5.368 \times 10^{-4} wy^3, \ \% = 88.6, \ F = 1645$$

$$F_y = 1.273 + 2.249 \times 10^{-1} \alpha - 1.129 y + 4.797 \times 10^{-3} y^3, \ \% = 69.4, \ F = 481$$

$$F_y = -1.248 + 2.249 \times 10^{-1} \alpha - 3.702 \times 10^{-1} wy + 1.565 \times 10^{-3} wy^3 + 3.102 \times 10^{-1} Vx, \ \% = 79.0, \ F = 596$$

$$F_z = 1.680 \times 10 - 2.366 \times 10^{-1} \alpha + 3.343 \times 10^{-1} y - 1.490 \times 10^{-3} y^3, \ \% = 86.6, \ F = 1372$$

$$F_z = 1.719 \times 10 - 2.412 \times 10^{-1} \alpha + 4.018 \times 10^{-3} \alpha y - 1.786 \times 10^{-5} \alpha y^3, \ \% = 88.2, \ F = 1578$$

$$F = -1.477 + 2.652 \times 10^{-1} \alpha - 1.183 y + 5.041 \times 10^{-3} y^3, \ \% = 71.3, \ F = 526$$

$$F = -4.024 + 2.652 \times 10^{-1} \alpha - 3.878 \times 10^{-1} wy + 1.644 \times 10^{-3} wy^3 + 3.131 \times 10^{-1} Vx, \ \% = 79.5, \ F = 616$$

$$C_x = 5.311 \times 10^{-1} + 9.227 \times 10^{-2} \beta_{d_1} + 2.172 \times 10^{-1} y - 9.266 \times 10^{-4} y^3, \ \% = 66.6, \ F = 422$$

$$C_x = -5.312 \times 10^{-1} + 2.117 \times 10^{-1} \beta_{d_1} + 7.359 \times 10^{-2} wy - 3.130 \times 10^{-4} wy^3 - 1.327 \times 10^{-3} \alpha\beta_{d_1}, \ \% = 70.9, \ F = 386$$

$$C_y = -1.857 \times 10 + 6.878 \times 10^{-1} y - 2.904 \times 10^{-3} y^3 + 6.942 \times 10^{-2} \alpha, \ \% = 14.0, \ F = 34$$

$$C_y = -1.570 \times 10 + 8.04 \times 10^{-4} \alpha\beta_d - 2.549 \times 10^{-1} wx + 2.894 \times 10^{-1} Vy + 2.639 \times 10^{-3} \beta_{d_1}\beta_i - 3.33 \times 10^{-4} Vw\alpha\beta_{d_1} - 1.195 \times 10^{-3} Vy^3, \ \% = 34.6, \ F = 56$$

$$C_z = -6.681 + 9.789 \times 10^{-2} \alpha - 2.004 \times 10^{-1} y + 8.673 \times 10^{-4} y^3, \ \% = 55.9, \ F = 269$$

$$C_z = -6.912 + 1.684 \times 10^{-1} \alpha - 2.365 \times 10^{-3} \alpha y + 1.017 \times 10^{-5} \alpha y^3 - 7.53 \times 10^{-4} \alpha\beta_d + 9.2 \times 10^{-5} Vw\alpha\beta_{d_1}, \ \% = 64.0, \ F = 225$$

$$C = -1.765 \times 10 + 7.249 \times 10^{-1} y - 3.065 \times 10^{-3} y^3 + 5.437 \times 10^{-2} \alpha, \ \% = 13.5, \ F = 33$$

$$C = -1.149 \times 10 + 3.333 \times 10^{-1} \beta_{d_1} - 3.61 \times 10^{-4} Vw\alpha\beta_{d_1} - 2.596 \times 10^{-1} wx + 8.182 \times 10^{-3} \alpha y - 3.438 \times 10^{-5} \alpha y^3 + 8.908 \times 10^{-1} V, \ \% = 36.5, \ F = 61$$

$$TX = 7.620 \times 10^{-1} - 4.600 \times 10^{-3} \alpha - 2.185 \times 10^{-2} y + 9.643 \times 10^{-5} y^3, \ \% = 19.3, \ F = 51$$

$$TX = -1.366 \times 10^{-1} + 5.178 \times 10^{-3} \alpha - 3.848 \times 10^{-2} V + 3.222 \times 10^{-1} w - 3.217 \times 10^{-3} w\alpha - 2.491 \times 10^{-4} \alpha y + 1.089 \times 10^{-6} \alpha y^3, \ \% = 29.8, \ F = 45$$

$$TZ = 2.251 + 2.456 \times 10^{-1} V - 2.1 \times 10^{-5} Vw\beta_{d_1}\beta_i, \ \% = 12.7, \ F = 46$$

$$TZ = 2.323 + 7.108 \times 10^{-2} Vw - 1.36 \times 10^{-4} Vw\beta_{d_1}\beta_i + 1.19 \times 10^{-4} Vw\alpha\beta_{d_1}, \ \% = 22.5, \ F = 62$$

Notes:
1. %* indicates the percent of the total variation which is accounted for by the associated equation.
2. F** is the statistical F for the associated equation. These F values are significant at the 1% level for all equations.
3. $\beta_{d_1} = \beta_d - 90^\circ$.

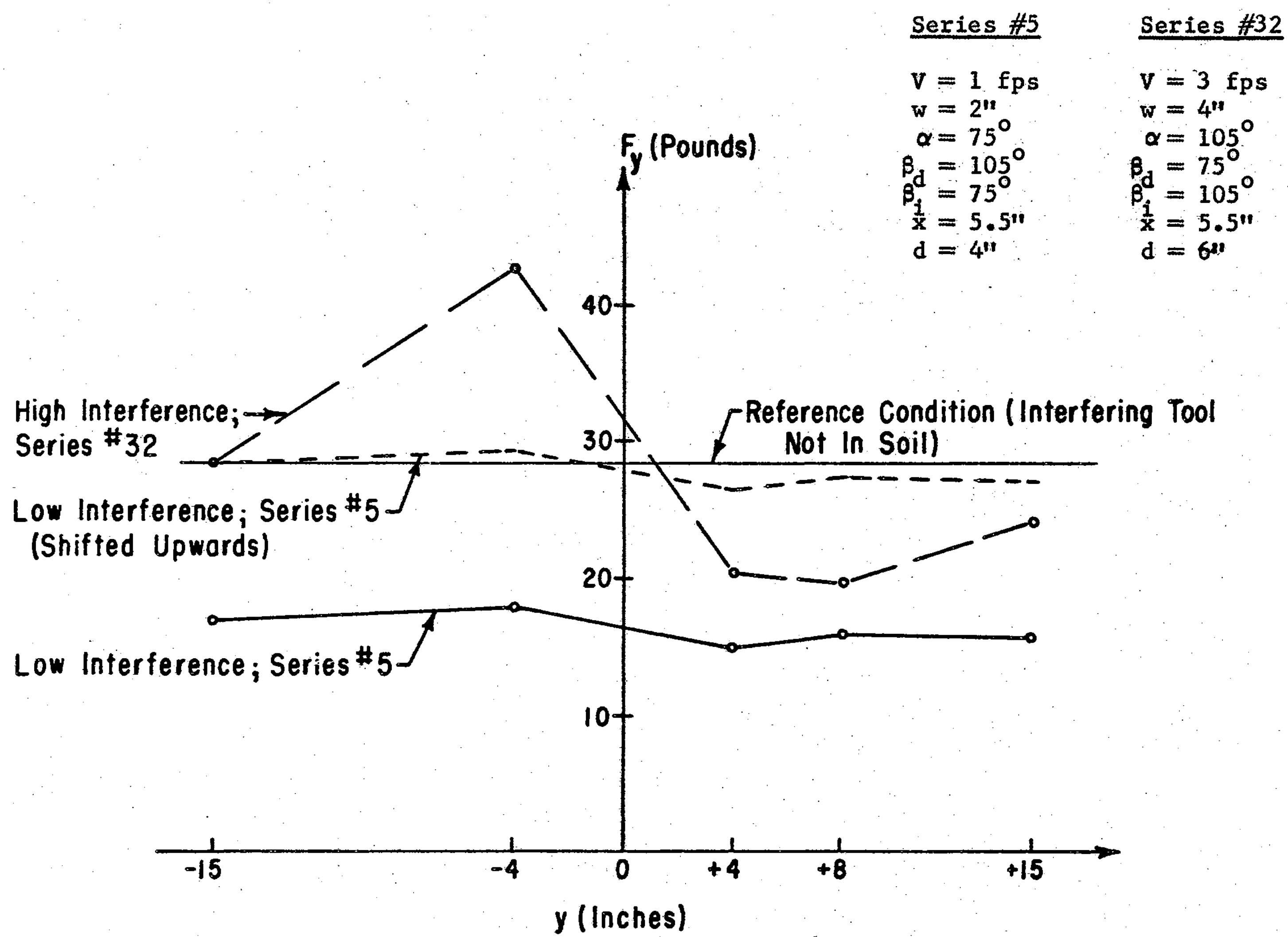


Figure 19. High and Low Interference Cases

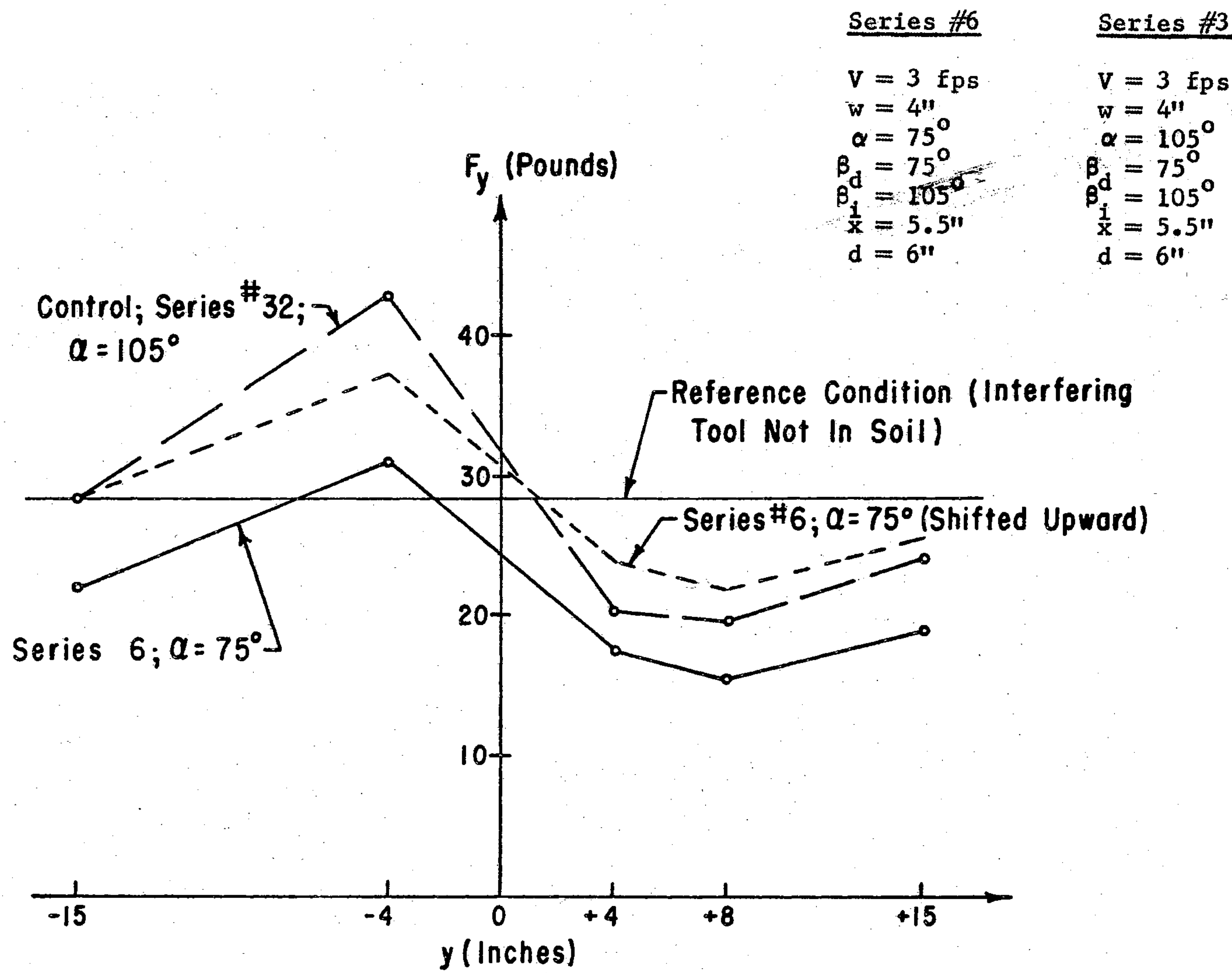


Figure 20. Effects of α at High Interference

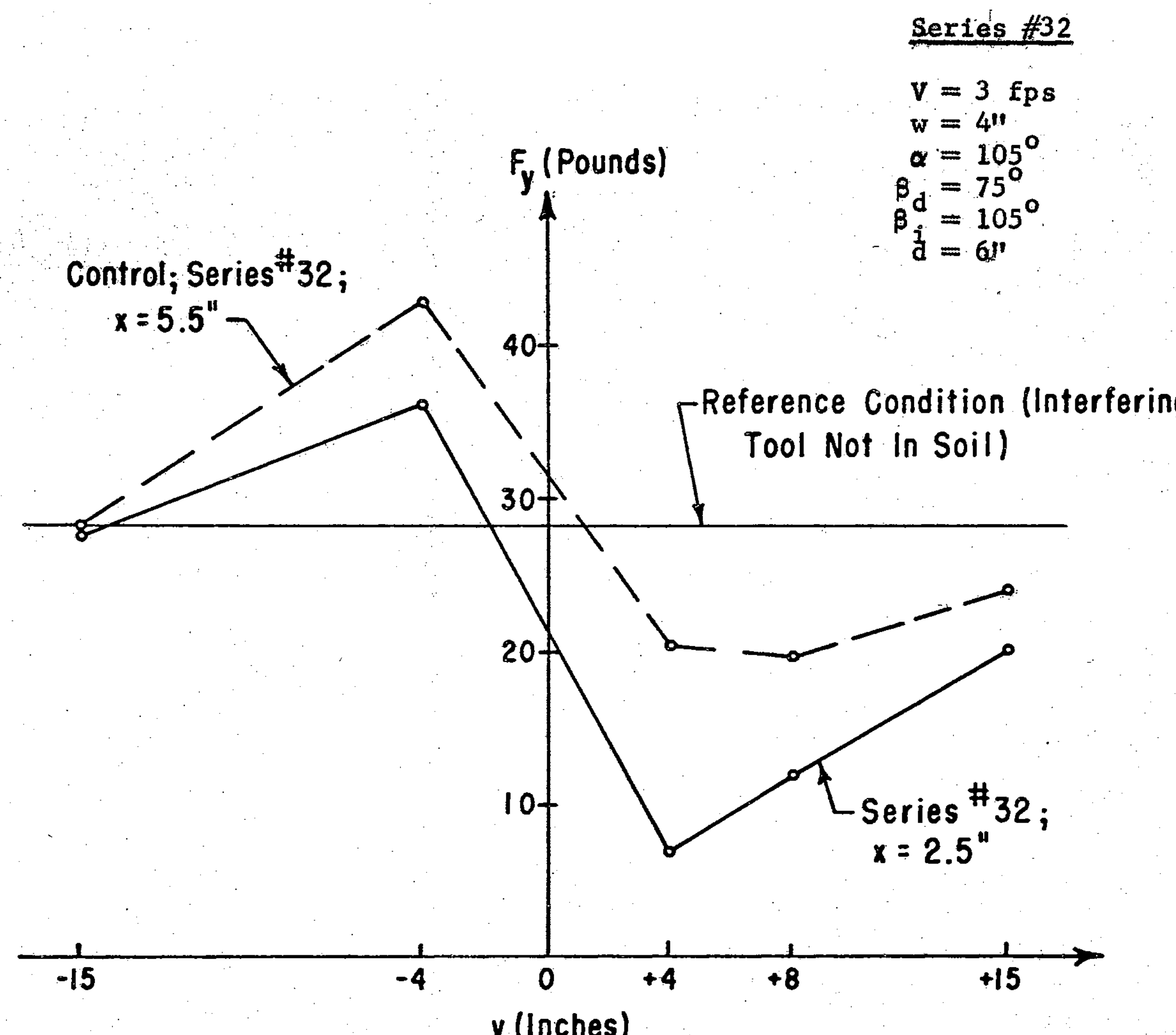


Figure 21. Effects of x at High Interference

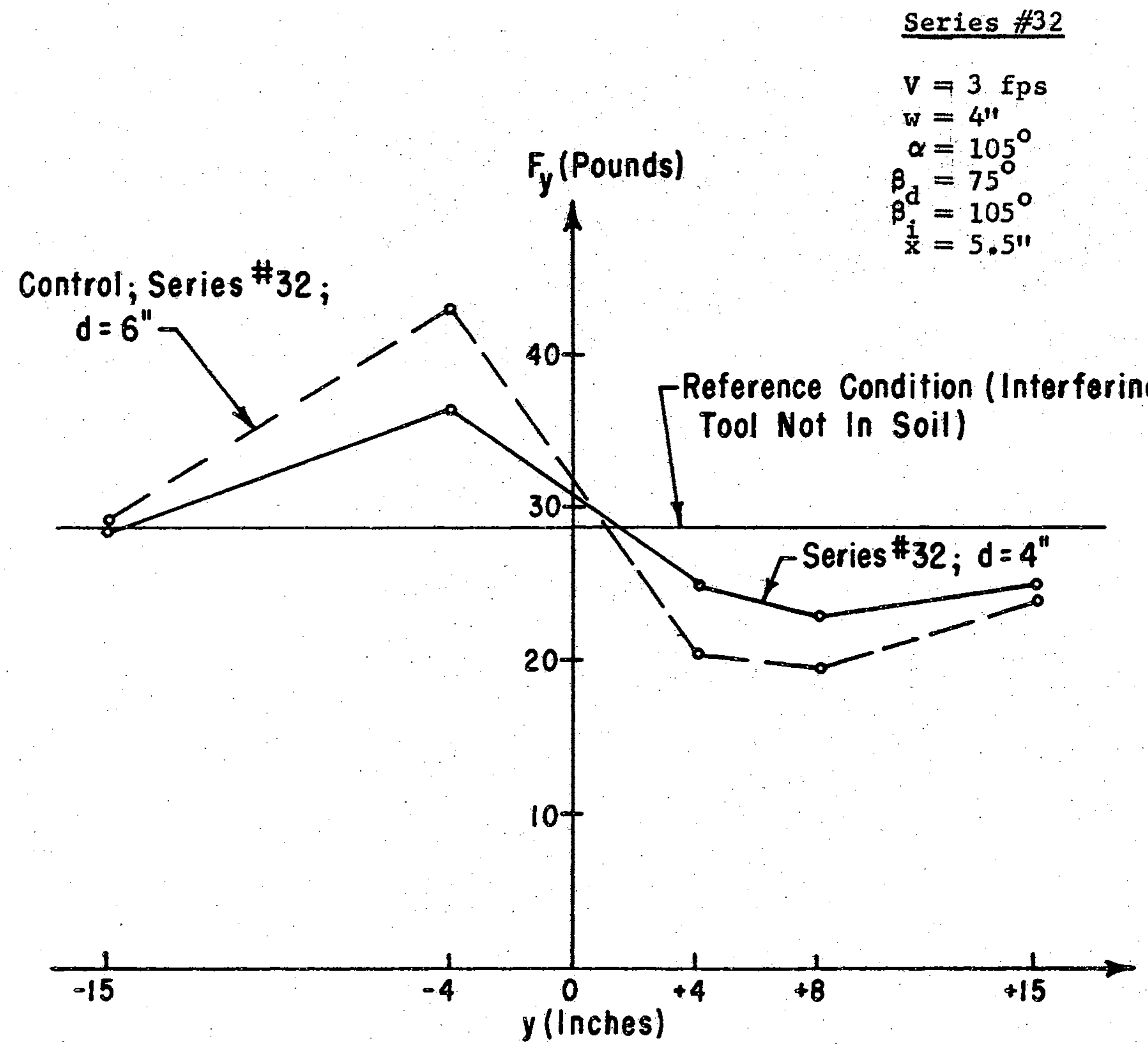


Figure 22. Effects of d at High Interference

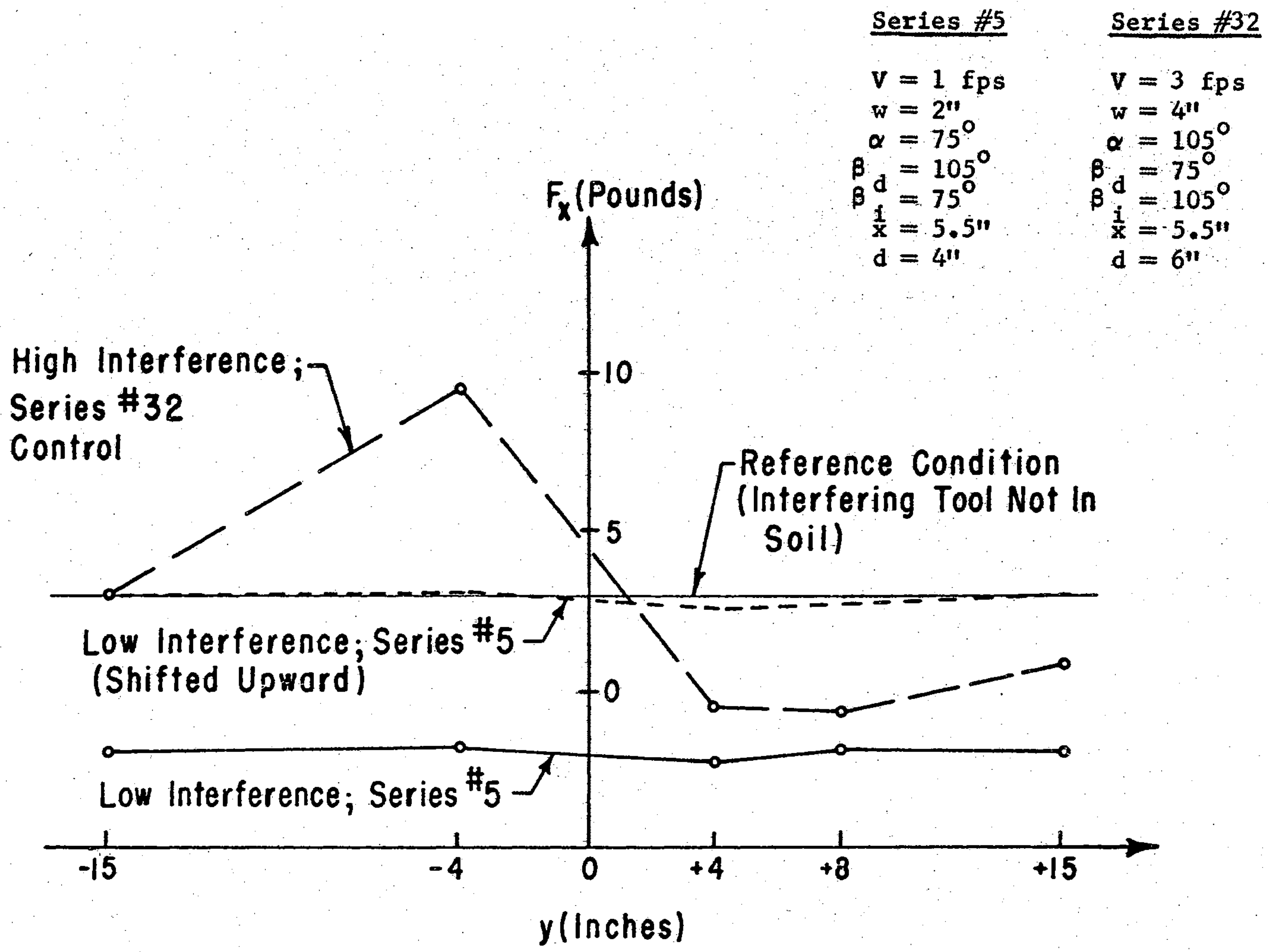


Figure 23. High and Low Interference Cases

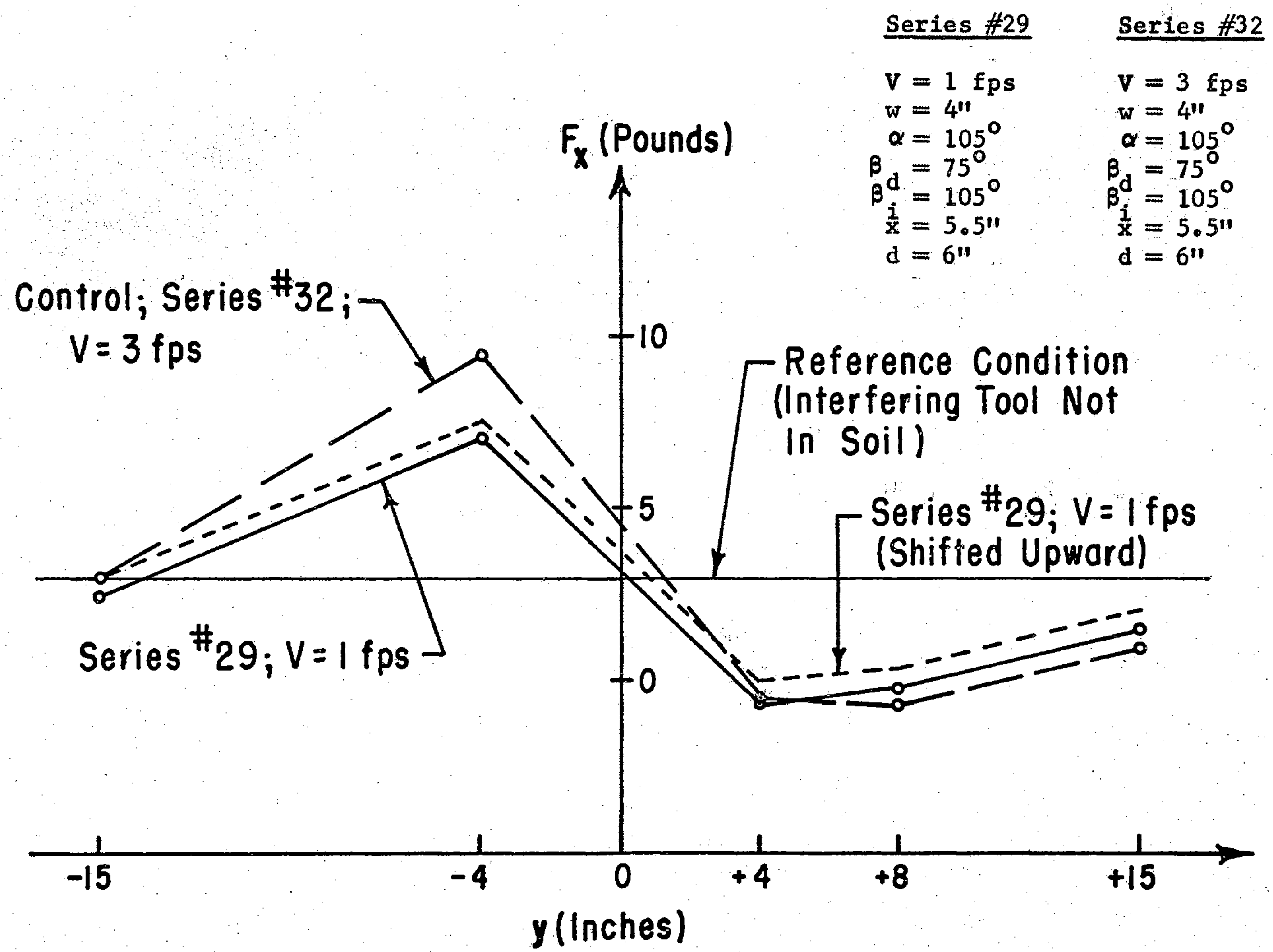


Figure 24. Effects of V at High Interference

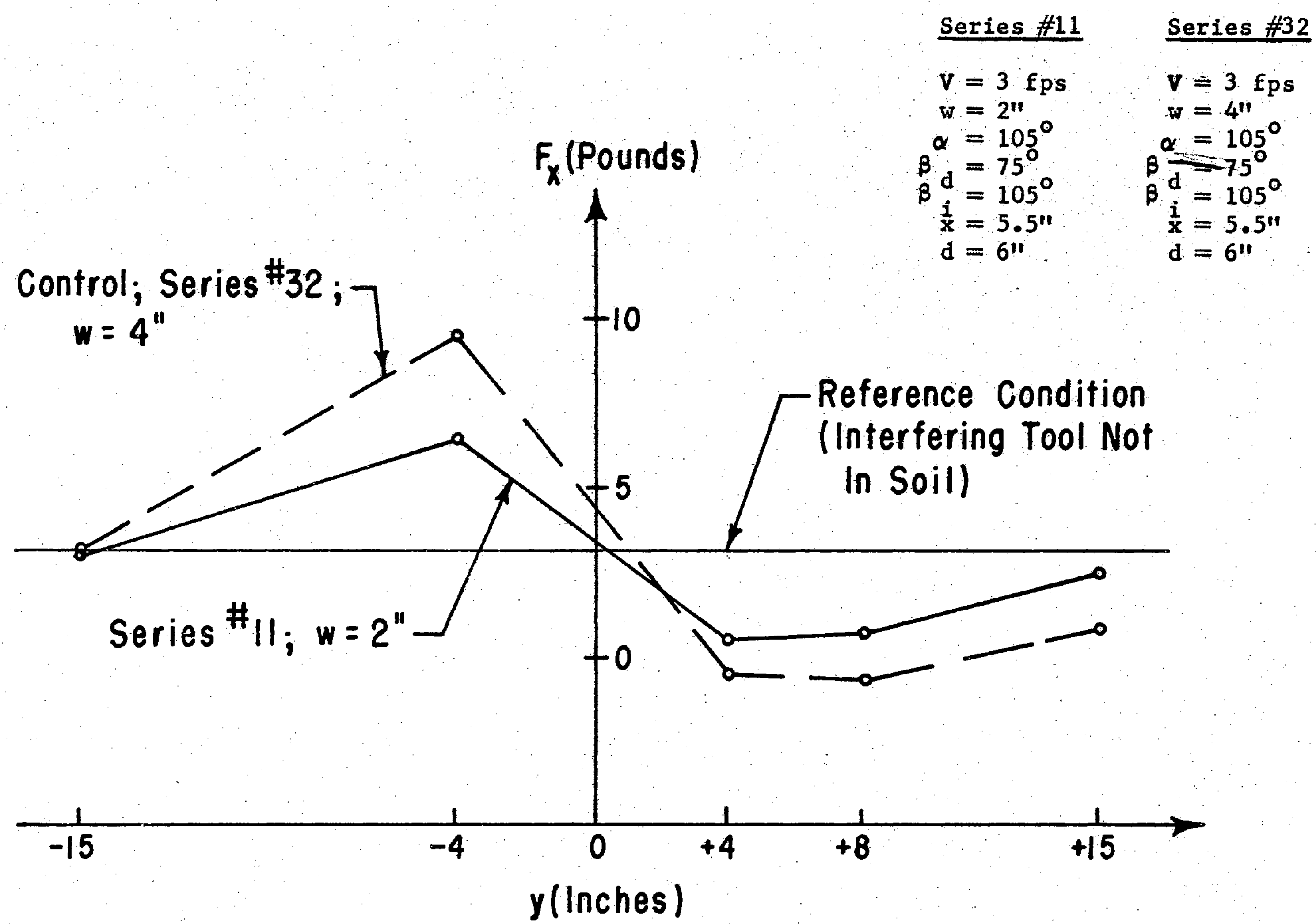


Figure 25. Effects of w at High Interference

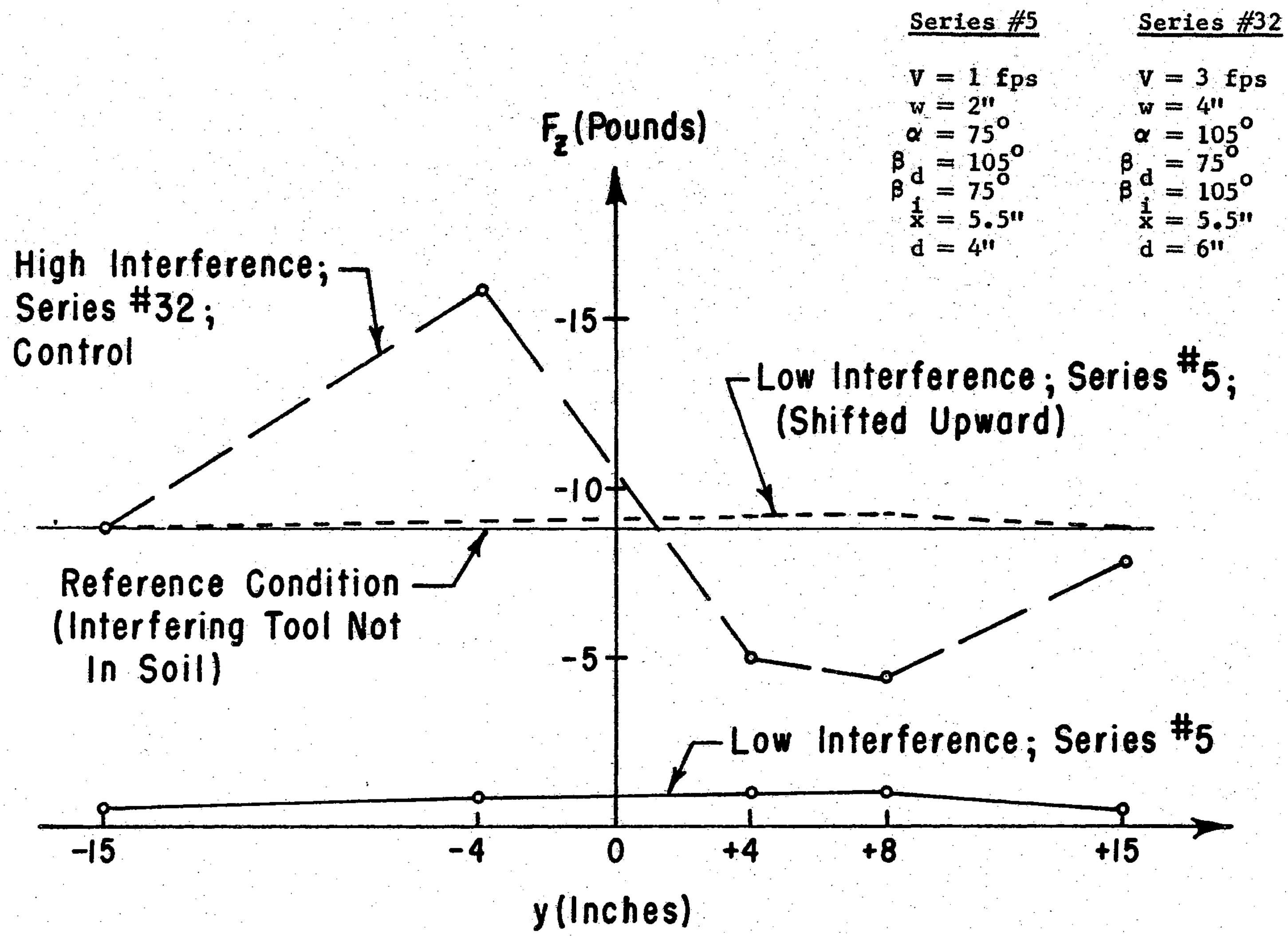


Figure 26. High and Low Interference Cases

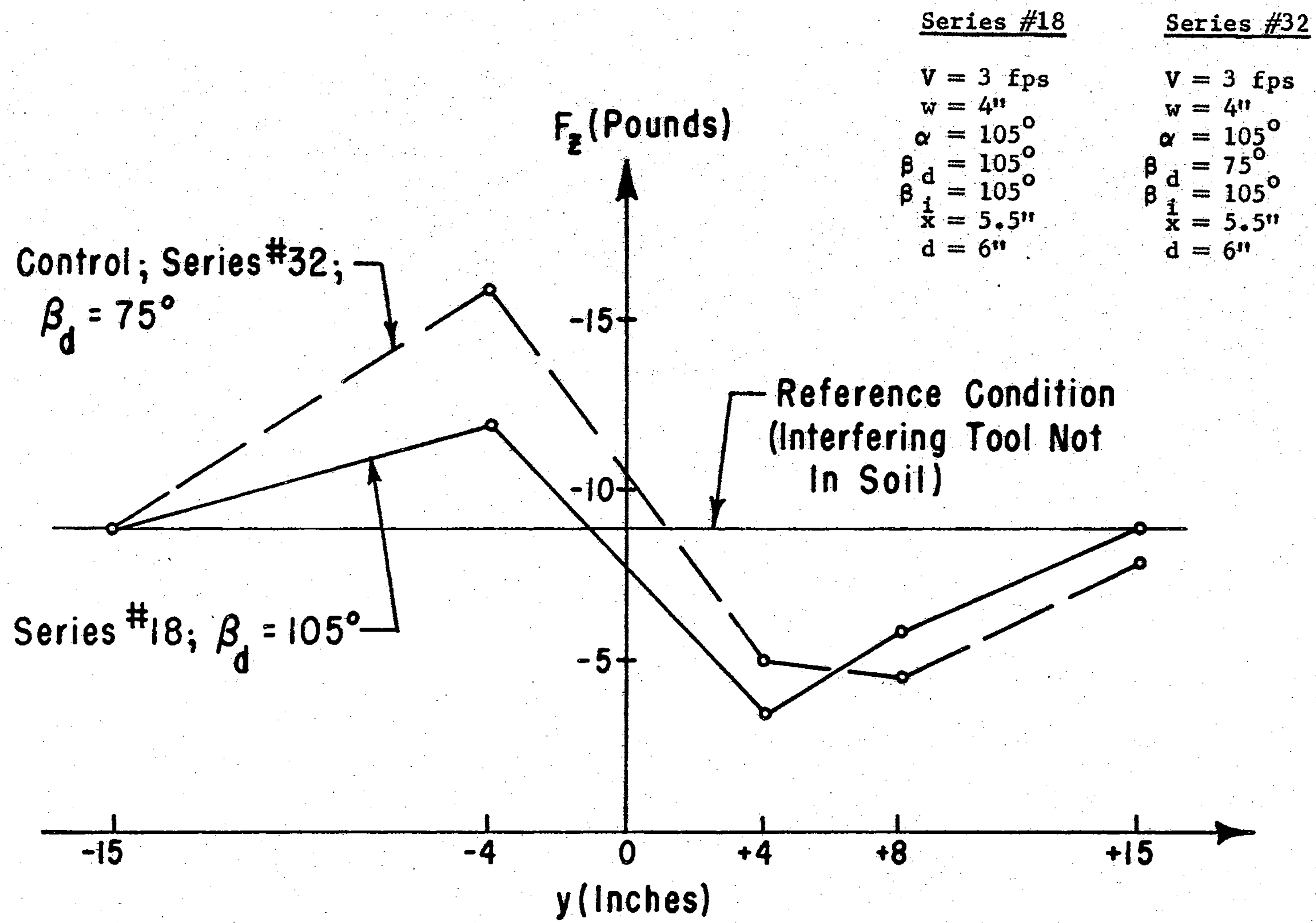


Figure 27. Effects of β_d at High Interference

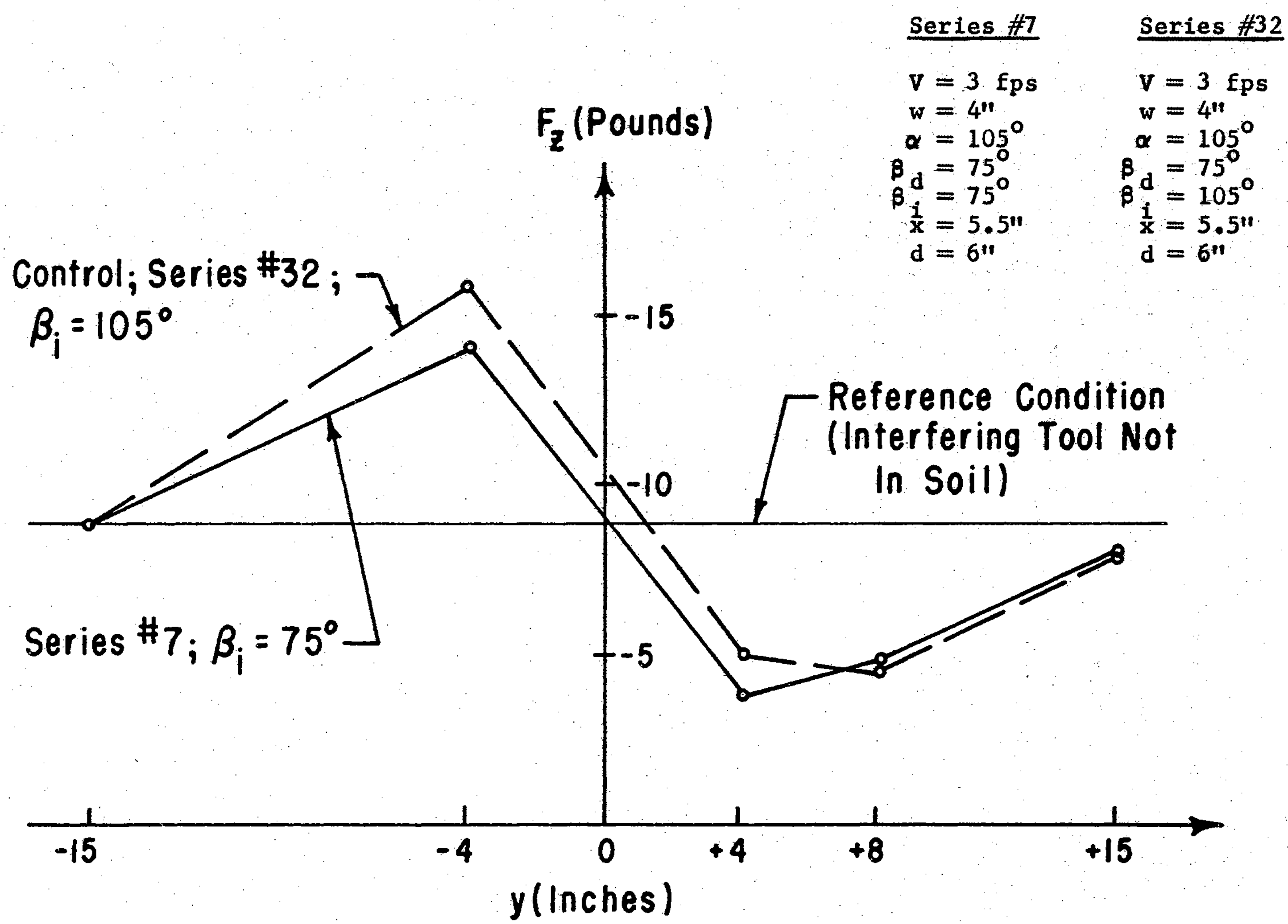


Figure 28. Effects of β_i at High Interference

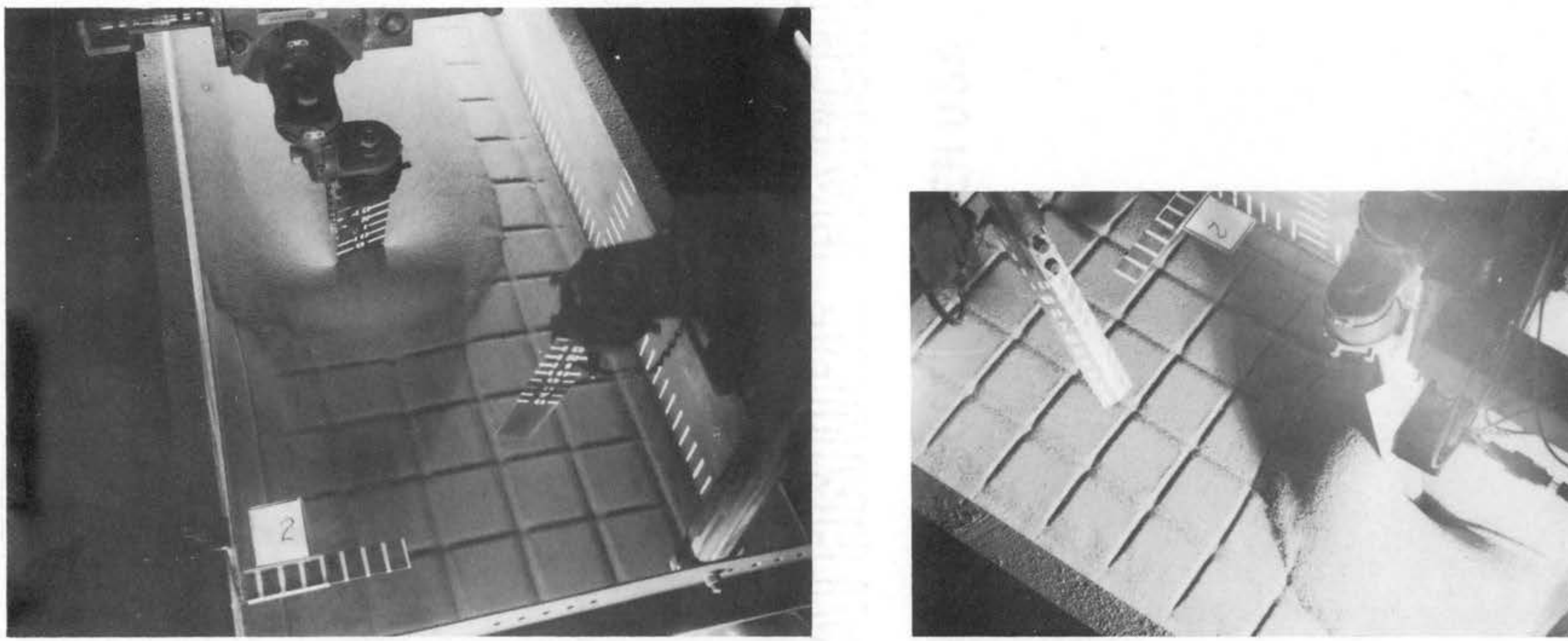
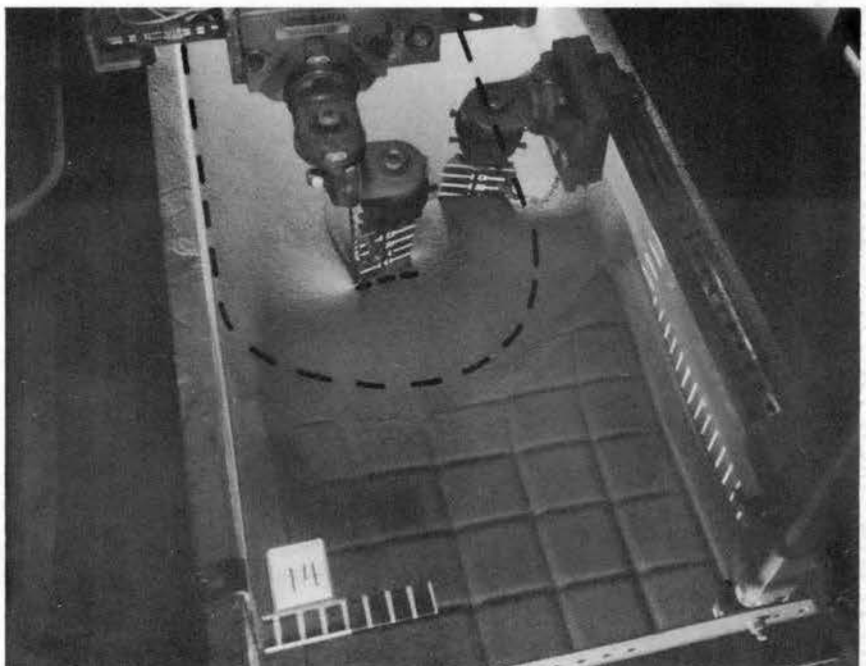


Figure 29. Reference Condition Without Interference ($V = 3$ fps, $\alpha = 105^\circ$, $\beta_d = 75^\circ$)

DATA BLOCK

Force Component	I Reference ($y = -15''$)	II $y = -4''$	III = II-I Change
F_y	28.3	42.8	14.5
F_x	3.0	9.5	6.5
$-F_z$	8.8	15.8	7.8



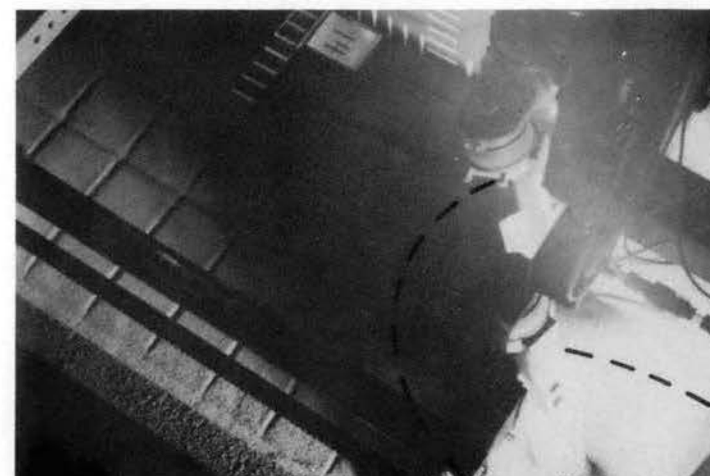


Figure 30. Effects of $y = -4''$ at High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^o$, $\beta_d = 75^o$, $\beta_i = 105^o$, $x = 5.5''$, $d = 6''$). Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 29, Reference Condition Without Interference ($V = 3$ fps, $\alpha = 105^o$, $\beta_d = 75^o$).

Force Component	I Reference (y = -15")	II y = +4"	III = II-I Change
F_y	28.3	20.5	-7.8
F_x	3.0	- 0.5	-3.5
$-F_z$	8.8	5.0	-3.8

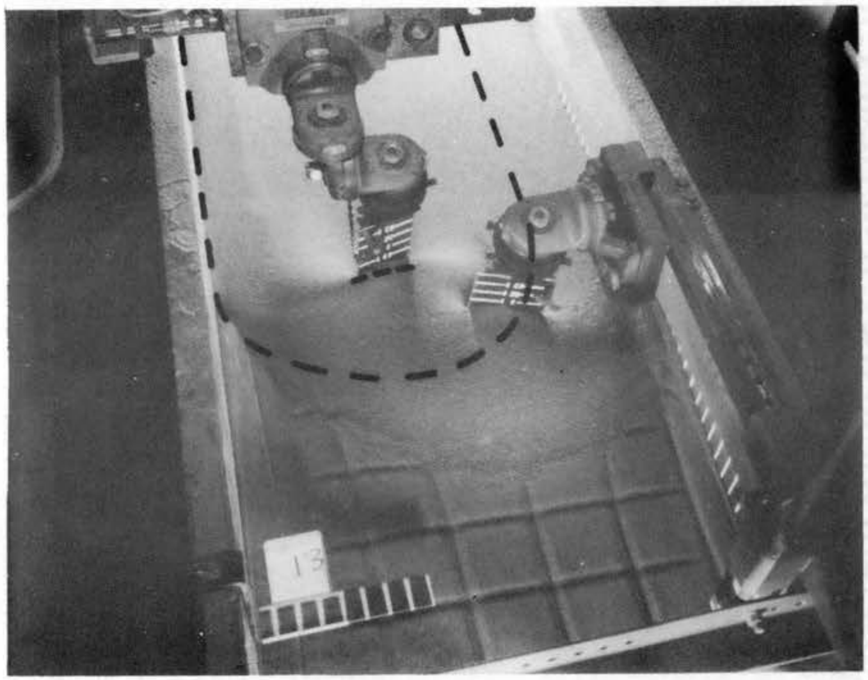


Figure 31. Effects of y = +4" at High Interference (V = 3 fps, w = 4", $\alpha = 105^\circ$, $\beta_d = 75^\circ$, $\beta_i = 105^\circ$, x = 5.5", d = 6"). Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 29, Reference Condition Without Interference (V = 3 fps, $\alpha = 105^\circ$, $\beta_d = 75^\circ$).

	DATA BLOCK		
	I	II	III = II-I
Force Component	Reference (y = -15")	y = +8"	Change
F_y	28.3	19.5	-8.8
F_x	3.0	- 0.7	-3.7
$-F_z$	8.8	4.5	-4.3

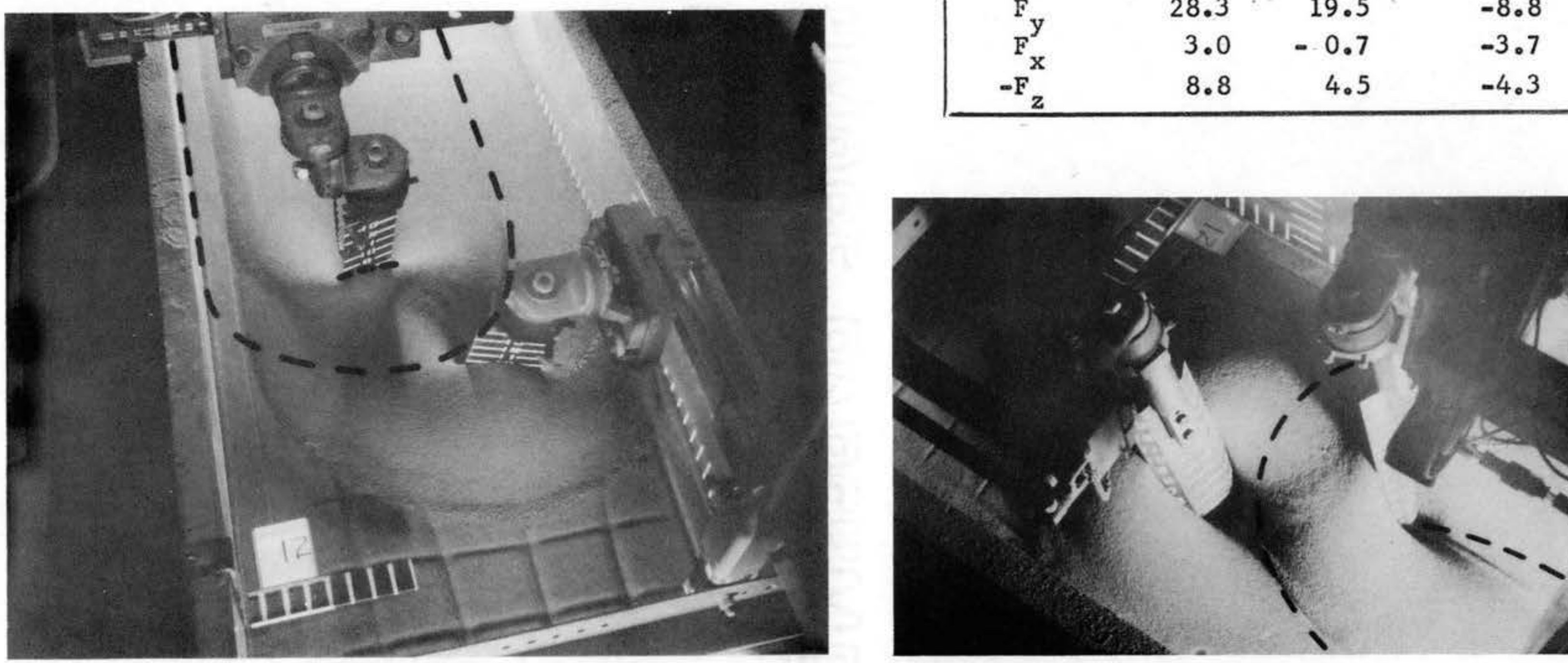
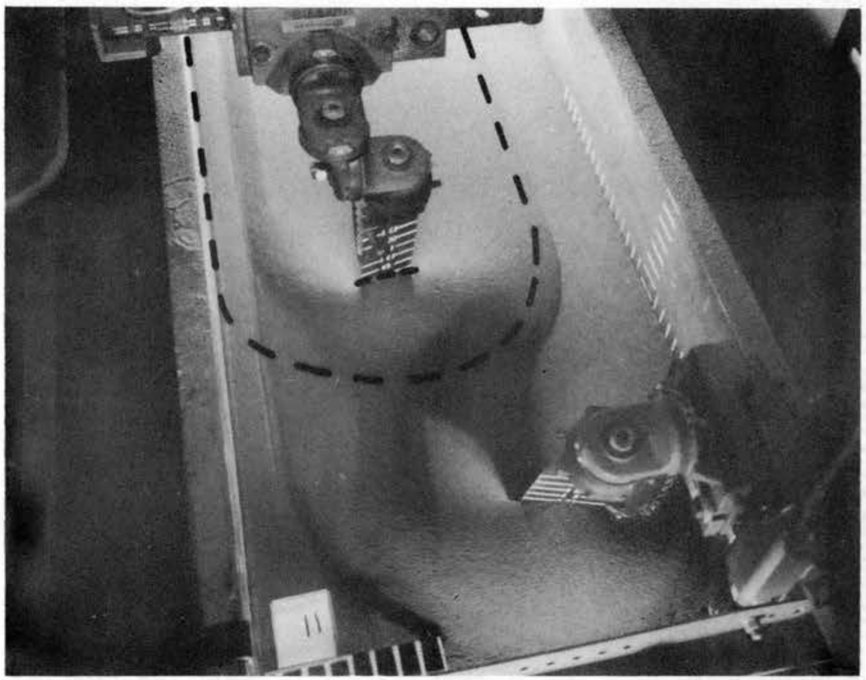


Figure 32. Effects of y = +8" at High Interference (V = 3 fps, w = 4", $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $\beta_i = 105^{\circ}$, x = 5.5", d = 6"). This Setup is the Control Condition for High Interference. Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 29, Reference Condition Without Interference (V = 3 fps, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$).

Force Component	I Reference (y = -15")	II y = +15"	III = II-I Change
F_y	28.3	24.0	-4.3
F_x	3.0	0.8	-2.2
$-F_z$	8.8	7.8	-1.0



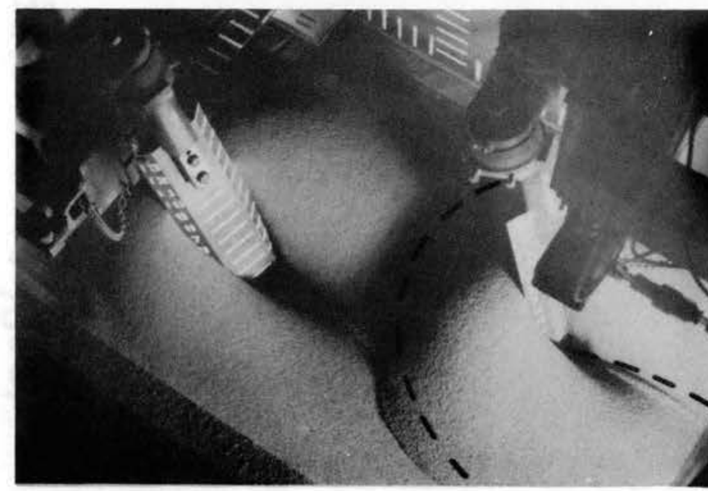
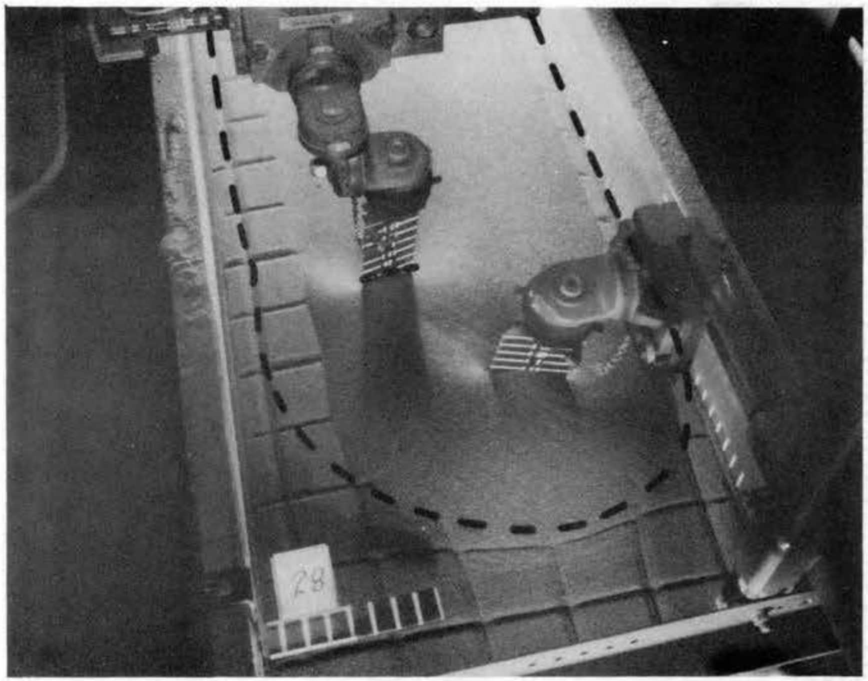


Figure 33. Effects of $y = +15''$ at High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^\circ$, $\beta_d = 75^\circ$, $\beta_i = 105^\circ$, $x = 5.5''$, $d = 6''$). Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 29, Reference Condition Without Interference ($V = 3$ fps, $\alpha = 105^\circ$, $\beta_d = 75^\circ$).

		DATA BLOCK	
	I	II	III = II-I
Force Component	Control V = 3 fps	V=1 fps (adj.)	Change
F_y	19.5	19.3	-0.2
F_x	- 0.7	0.2	+0.9
$-F_z$	4.5	5.5	+1.0



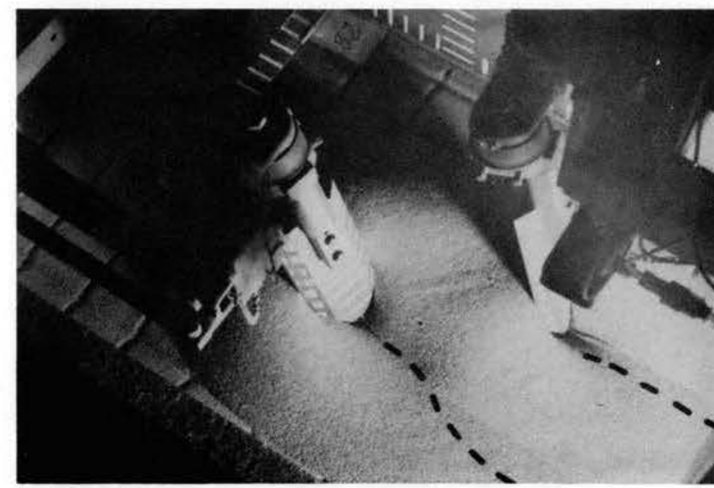
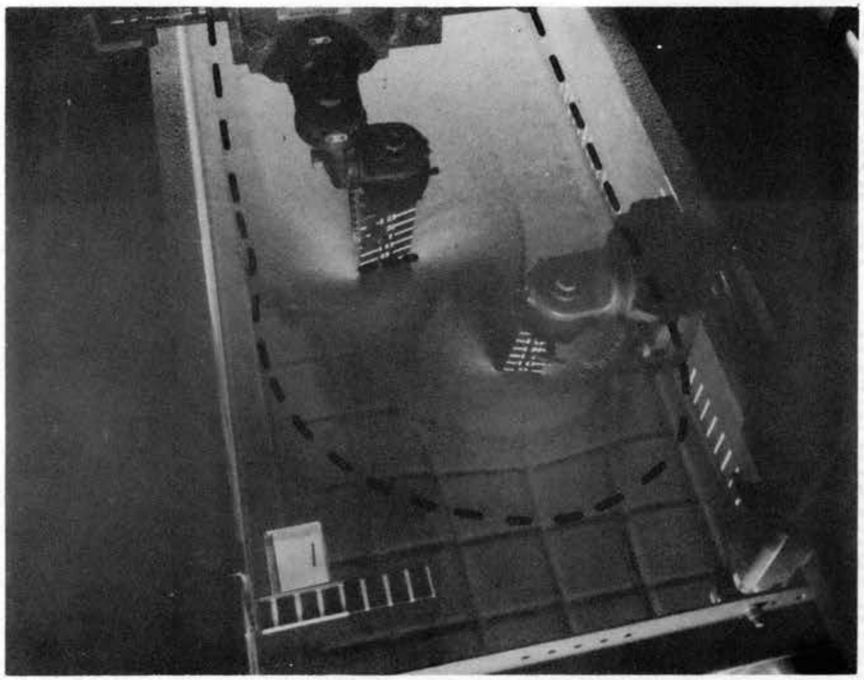


Figure 34. Effects of V = 1 fps at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $\beta_i = 105^{\circ}$, $x = 5.5''$, $y = +8''$, $d = 6''$).

DATA BLOCK

Force Component	I Control w = 4"	II w = 2"	III = II-I Change
F_y	19.5	21.5	+2.0
F_x	- 0.7	0.7	+1.4
$-F_z$	4.5	6.0	+1.5



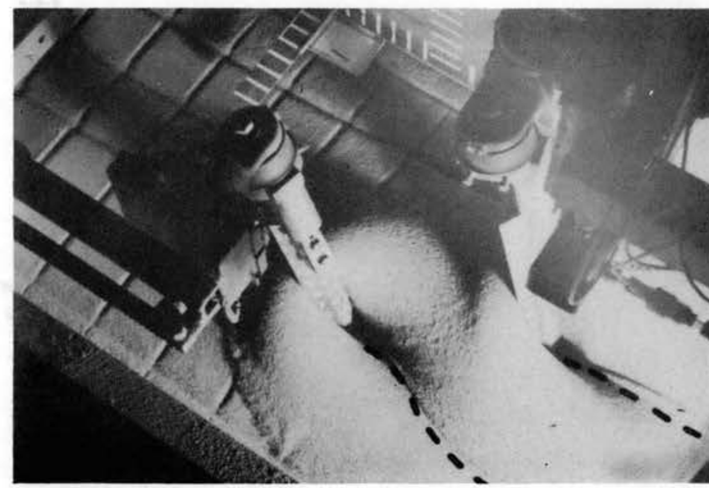
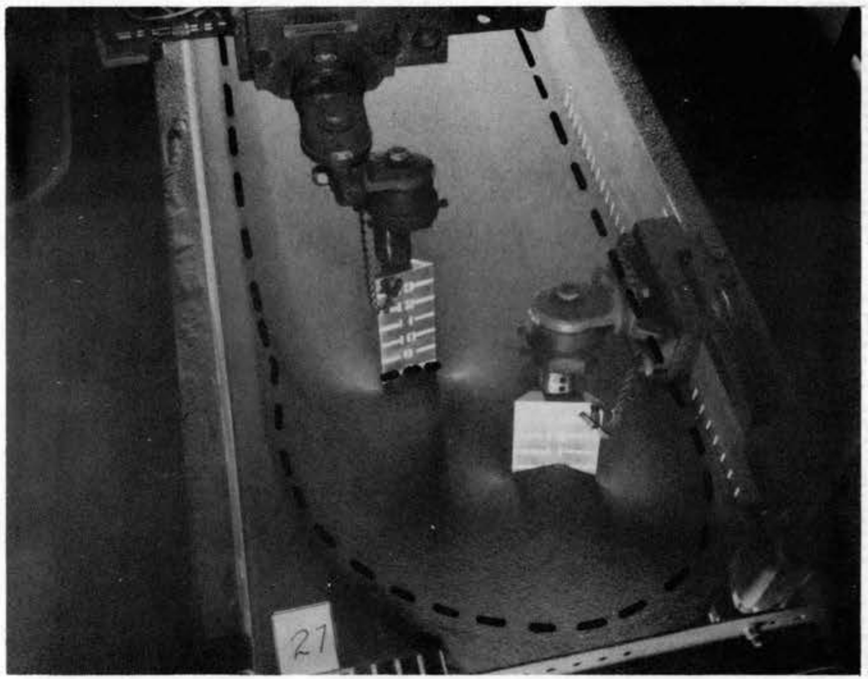


Figure 35. Effects of w = 2" at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference (V = 3 fps, w = 4", $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $\beta_i = 105^{\circ}$, x = 5.5", y = +8", d = 6").

DATA BLOCK

Force Component	I Control $\alpha = 105^{\circ}$	II $\alpha = 75^{\circ}$ (adj.)	III = II-I Change
F_y	19.5	21.8	+2.3
F_x	- 0.7	0.1	+0.8
$-F_z$	4.5	7.1	+2.6



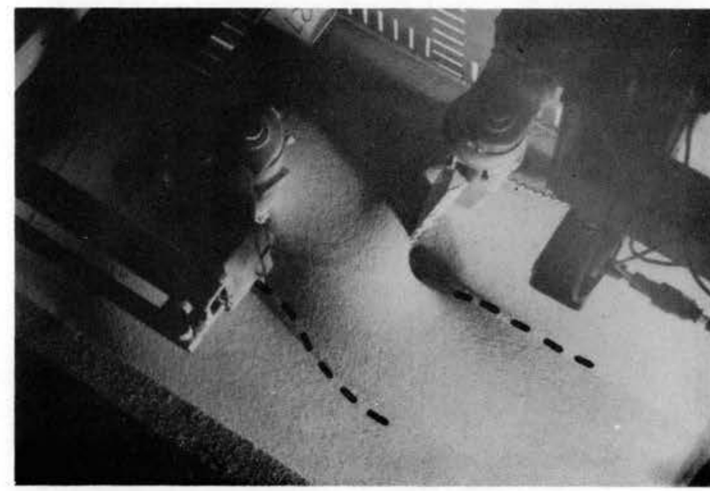
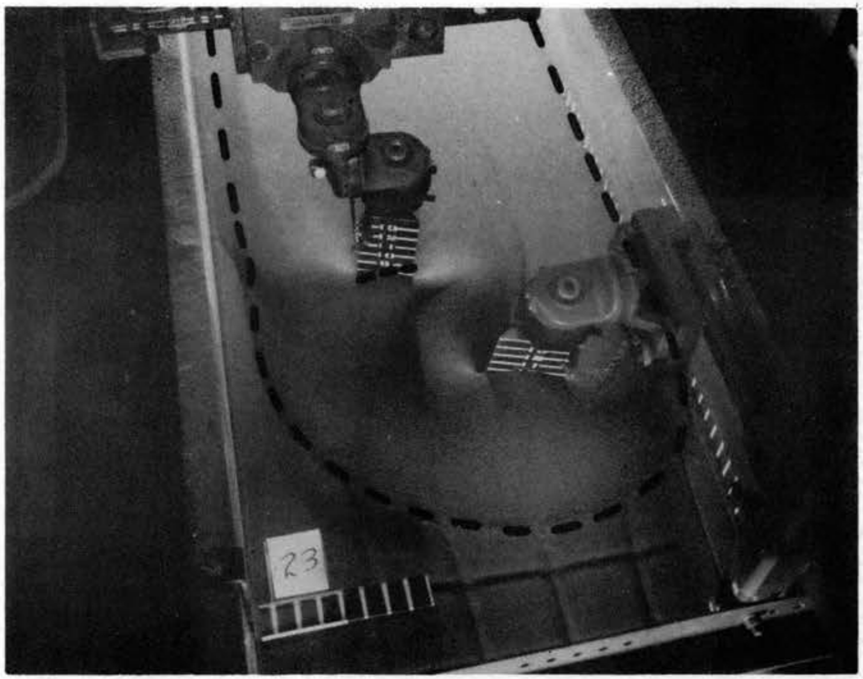


Figure 36. Effects of $\alpha = 75^{\circ}$ at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $\beta_i = 105^{\circ}$, $x = 5.5''$, $y = +8''$, $d = 6''$).

Force Component	I Control $\beta_d = 75^o$	II $\beta_d = 105^o$ (adj.)	III = II-I Change
F_y	19.5	22.0	+2.5
F_x	- 0.7	0.6	+1.3
$-F_z$	4.5	5.8	+1.3

DATA BLOCK



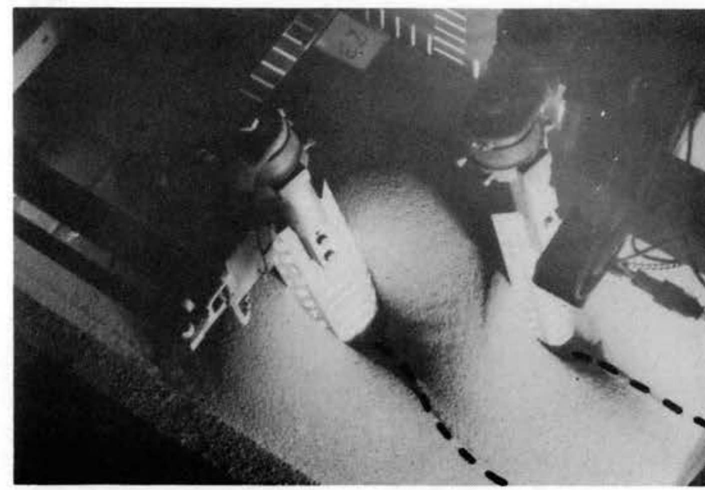
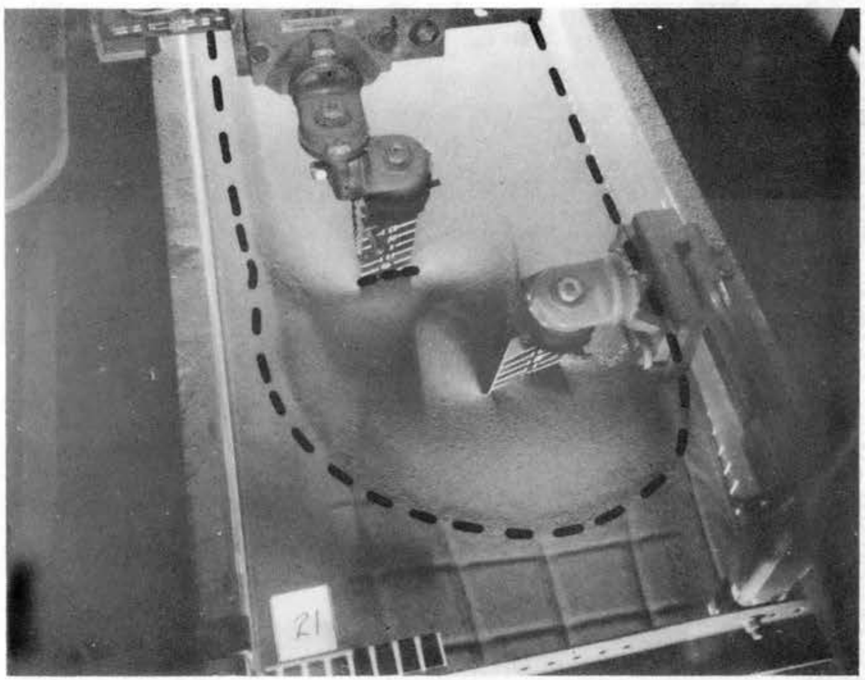


Figure 37. Effects of $\beta_d = 105^o$ at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^o$, $\beta_d = 75^o$, $\beta_i = 105^o$, $x = 5.5''$, $y = +8''$, $d = 6''$).



DATA BLOCK

Force Component	I Control $\beta_i = 105^{\circ}$	II $\beta_i = 75^{\circ}$	III = II-I Change
F_y	19.5	17.5	-2.0
F_x	- 0.7	- 0.4	+0.3
$-F_z$	4.5	4.8	+0.3

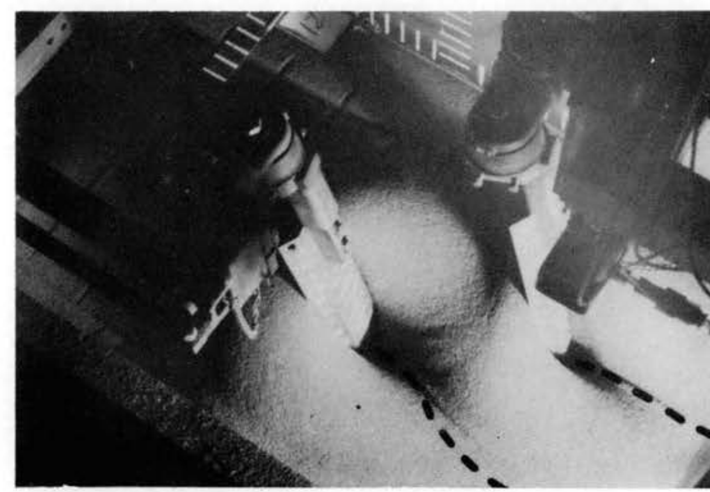
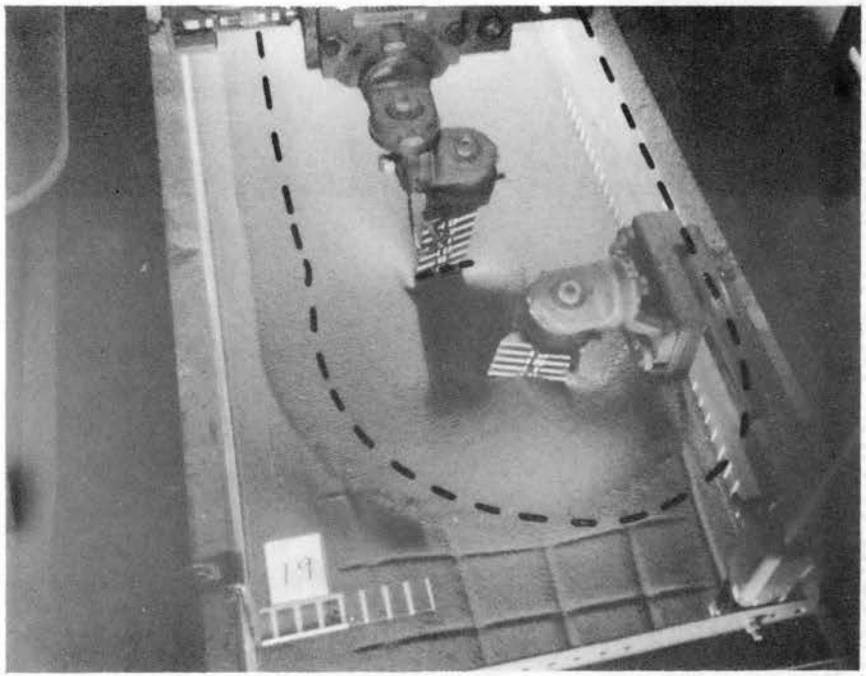


Figure 38. Effects of $\beta_i = 75^{\circ}$ at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4''$, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $\beta_i = 105^{\circ}$, $x = 5.5''$, $y = +8''$, $d = 6''$).

DATA BLOCK

Force Component	I Control x = 5.5"	II x = 2.5"	III = II-I Change
F_y	19.5	11.8	-7.7
F_x	- 0.7	- 0.4	+0.3
$-F_z$	4.5	3.0	-1.5



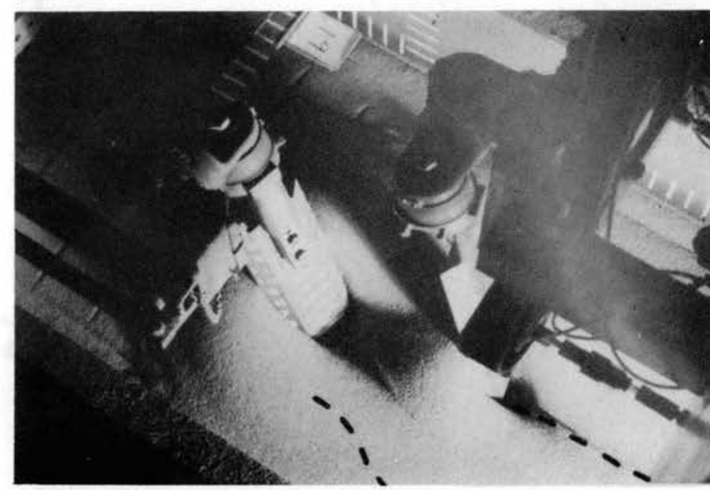
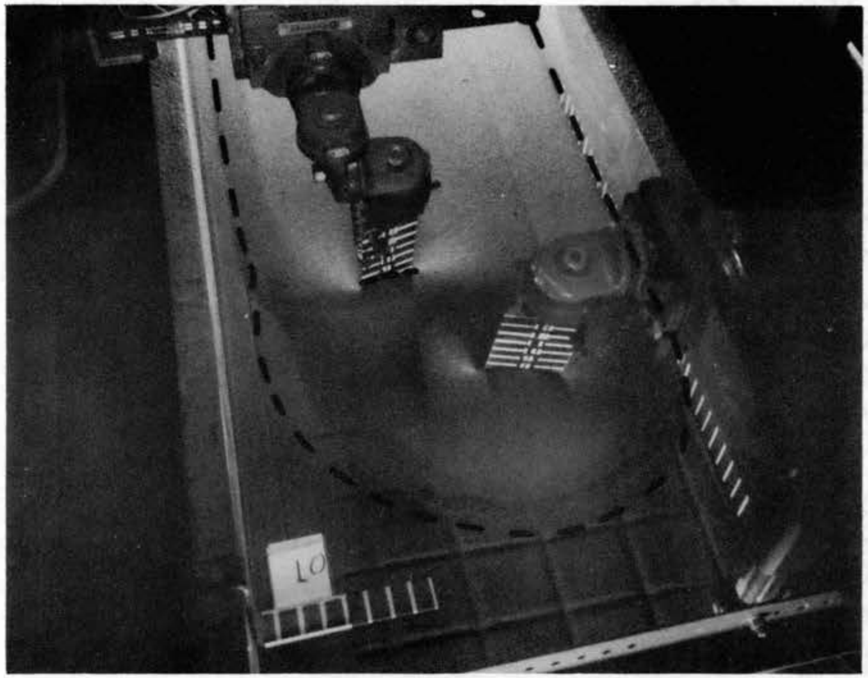


Figure 39. Effects of x = 2.5" at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4"$, $\alpha = 105^\circ$, $\beta_d = 75^\circ$, $\beta_i = 105^\circ$, $x = 5.5"$, $y = +8"$, $d = 6"$).

	DATA BLOCK		
	I	II	III = II-I
Force Component	Control d = 6"	d = 4"	Change
F_y	19.5	23.0	+3.5
F_x	- 0.7	0.3	+1.0
$-F_z$	4.5	7.0	+2.5



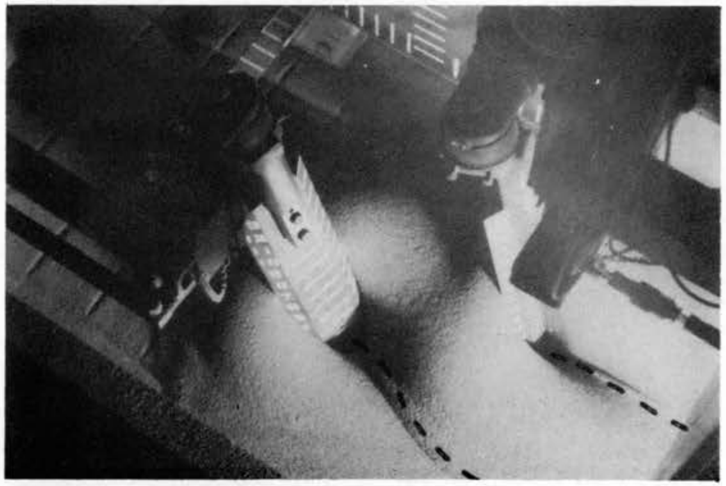
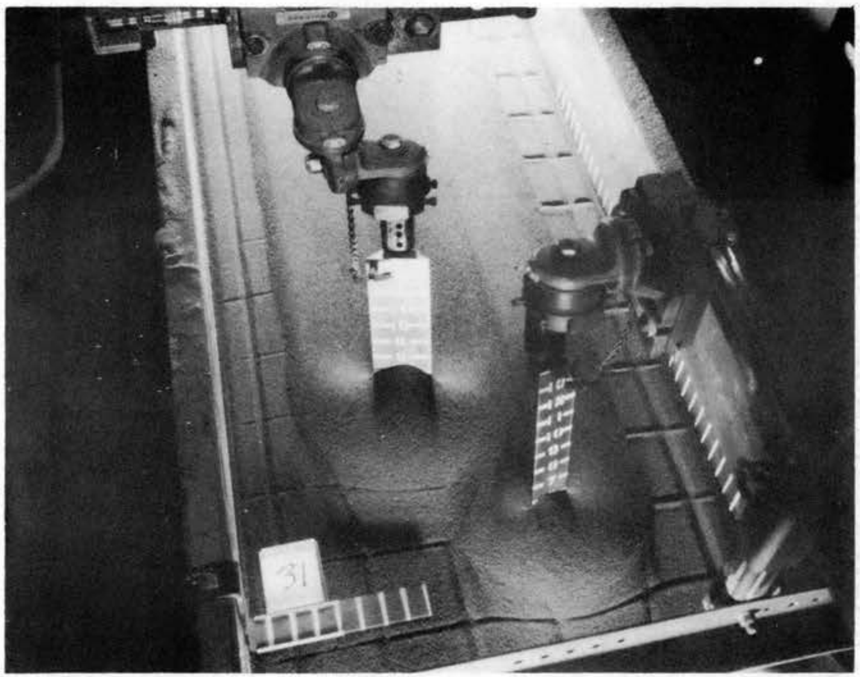


Figure 40. Effects of d = 4" at High Interference. The Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 32, Control Condition for High Interference ($V = 3$ fps, $w = 4"$, $\alpha = 105^\circ$, $\beta_d = 75^\circ$, $\beta_i = 105^\circ$, $x = 5.5"$, $y = +8"$, $d = 6"$).

DATA BLOCK			
Force Component	I Reference (y = -15")	II Low Int.	III = II-I Change
F_y	16.8	15.8	-1.0
F_x	- 1.9	- 1.9	0.0
$-F_z$	0.5	1.0	+0.5



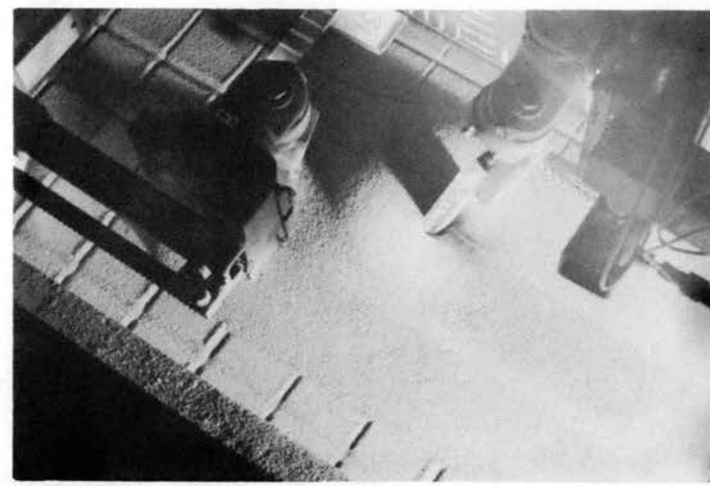


Figure 41. Low Interference Condition ($V = 1$ fps, $w = 2''$, $\alpha = 75^\circ$, $\beta_d = 105^\circ$, $\beta_i = 75^\circ$, $x = 5.5''$, $y = +8''$, $d = 4''$)

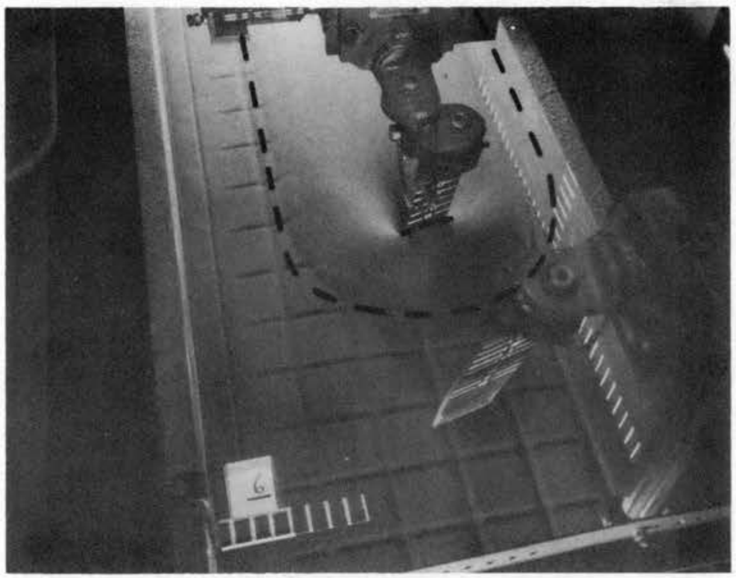


Figure 42a. Edge of Tool 7 Inches From Bin Side. Draft Force Affected to the Extent of 0.5 Pounds. No Measurable Effects on Other Tool Forces

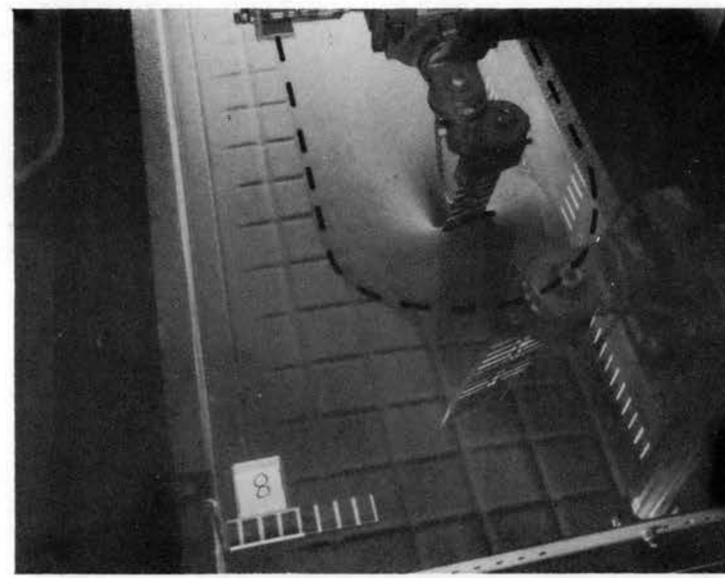


Figure 42b. Edge of Tool 5 Inches From Bin Side. Draft Force Affected to the Extent of 2 Pounds. No Measurable Effects on Other Tool Forces

Figure 42. Interference with Bin Side ($V = 3$ fps, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$). Superimposed Dashed Lines are Used to Represent the Flow Pattern From Figure 29, Reference Conditions Without Interference ($V = 3$ fps, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$)

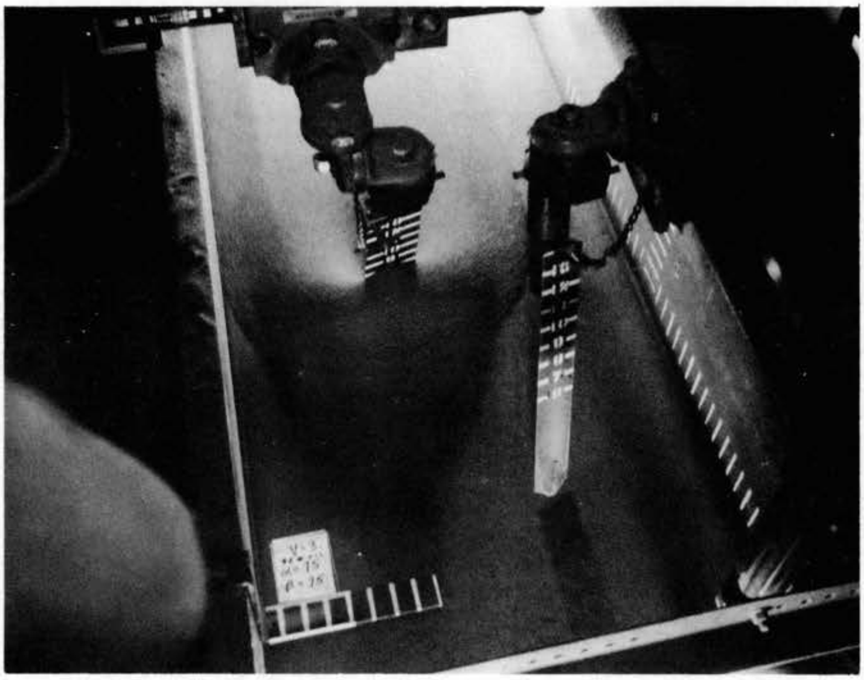


Figure 43. Views of Soil Body Formed on Tillage Tool ($V = 3$ fps, $w = 2''$, $\alpha = 75^\circ$, $\beta_i = 75^\circ$, $d \approx 6''$)

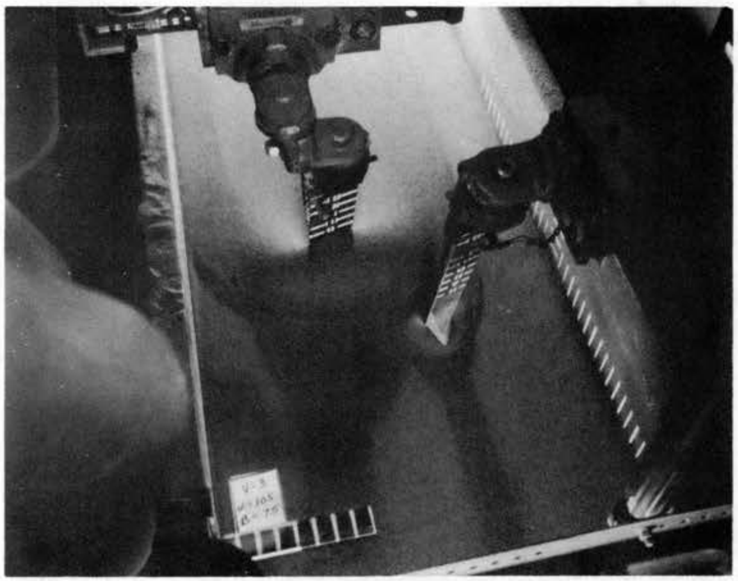


Figure 44. Soil Body Formed on Tillage Tool ($V = 3$ fps, $w = 2''$, $\alpha = 105^{\circ}$, $\beta_i = 75^{\circ}$, $d \approx 6''$).

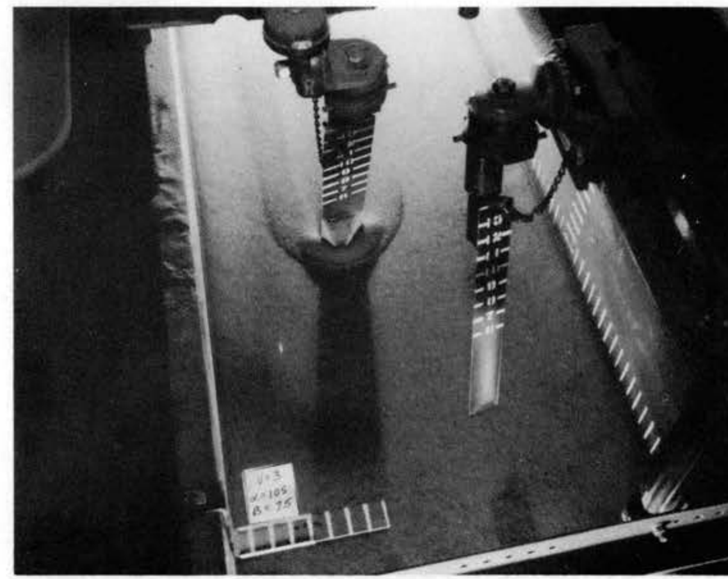


Figure 45. Soil Body Formed on Tillage Tool ($V = 3$ fps, $W = 3''$, $\alpha = 105^{\circ}$, $\beta_d = 75^{\circ}$, $d \approx 5''$)

Discussion of Results

The means and standard deviations of the dependent factors for all tests are given in Table I. This table is self-explanatory, so it will not be discussed.

The sum of squares partitionings and F tests are presented in Tables II thru XI. A summary of the sum of squares partitionings is given in Table XII. The information in these tables was obtained through use of an analysis of variance computer program for a factorial design (2). The total variation associated with each dependent factor was partitioned among 256 sources. These 256 sources consisted of 8 main effects, 247 interactions, and sampling error. Sampling error was associated with variations between observations #1 and #2.

The factorial program was organized as 32 series $[(2V)(2w)(2\alpha)(2\beta_d)(2\beta_i) = 32]$ with 20 tests $[(2x)(5y)(2d) = 20]$ in each series. This arrangement necessitated the use of two error terms: one error term for significance testing of terms involving x, y, or d and one error term for significance testing of terms not involving x, y, or d. Before conducting the experimental program, the Statistical Laboratory at Oklahoma State University was consulted for advice on statistical design of the experiment. Based on this consultation, as well as Natrella (11), the decision was made to pool 4 and 5 factor interactions not containing x, y, or d as Error #2. Error #2 would then be used for significance testing of 1, 2, and 3 factor terms which did not contain x, y, or d. Likewise, it was planned to pool sampling error and 4, 5, 6, 7, and 8 factor interactions which did involve x, y, or d as Error #4. Error #4 would then be used for significance testing of 1, 2, and 3 factor terms involving x, y, or d. In the planning of factorial experiments, it is frequently assumed that interactions higher than 3 factor will be nonsignificant, and therefore, they can be pooled as error estimates.

After the output from the computer program was obtained, it appeared that Error #4 could be satisfactorily applied in connection with all the dependent factors. However, Error #2 appeared to be an unsuitable error term for use in connection with some of the dependent factors. In the cases of C_y, C, TX, and TZ, it appeared that some of the components of Error #2 might have significant effects on the dependent factor. Consider $Vw\alpha\beta_d$ associated with C_y and C, $V\alpha\beta_d\beta_i$ associated with TX, and $Vw\beta_d\beta_i$ associated with TZ. Since Error #2 was inappropriate for use with C_y, C, TX, and TZ, no error term was available for significance testing of terms not involving x, y, or d for C_y, C, TX, and TZ.

In Tables II thru XI, the sources of variation are arranged so that the sum of squares values are in descending order, and only the first 15 sources are listed. In addition, the sources of variation are separated into three groups. The separation into these groups is somewhat arbitrary, but it does aid in the consideration of these tables. Each source in the first group accounts for a relatively large amount of the total variation of the dependent factor. Each source in the second group accounts for a lesser amount of the total variation, but each source in this group still accounts for a sizable proportion of the variation. Each source in the third group accounts for a relatively small proportion of the total variation. The three groups could each be considered as having two sub-groups where applicable. The first sub-group would contain sources of primary interest (related to interference), and the second sub-group would contain sources of lesser interest (not related to interference). The arrangement of the Analysis of Variance tables allows one to see where sum of squares concentrations lie, as well as displaying the percent of the total sum of squares which can be accounted for by a relatively few sources. It can be noted that for some dependent factors, over 90 percent of the variation can be accounted for by 3 sources. However, for other dependent factors, 15 sources account for less than half of the total variation. If a large proportion of the total variation of a dependent factor is associated with a relatively few sources, it is indicated that these sources have pronounced effects on the dependent factor. Also, with the presence of these concentrations, it may be possible to develop a simple prediction equation which will account for a large proportion of the total variation of the dependent factor. However, if the total sum of squares is attributed more or less evenly to a large number of sources, then it is indicated that no sources have particularly pronounced effects on the dependent quantity. Also, with widely distributed sums of squares, it will probably not be possible to develop a simple prediction equation that will account for a large proportion of the total variation.

With reference to the total variation associated with a dependent factor, this total variation can be considered in four groups. The first three groups have already been discussed. The fourth group involves experimental error. Experimental error is associated with variation in experimental material and variation due to lack of uniformity in the physical conduct of the experiment. The sums of squares associated with sources in the first three groups will have components involving experimental error. However, in at least the first two groups, the treatment components of the sums of squares will be relatively much larger than the experimental error components of the sums of squares. For the dependent factors F_x, F_y, F_z, and F, it can be noted that a relatively small number of sources account for a reasonably large proportion of the total variation. However, considering C_x, C_z, C_y, C, TX, and TZ, it can be noted that progressively smaller amounts of the total variation are accounted for by a few sources. With these dependent quantities, variation associated with error terms accounted for progressively larger amounts of the total variation. In the cases of C_x and C_z, appropriate error terms are available, and these can be used to help separate sources into the groups previously mentioned. However, in the cases of C_y, C, TX, and TZ, Error #2 is not an appropriate error term, and therefore, it is difficult to assess the significance of the source effects. The portion of the total variation that is associated with error terms is not available to be attributed to other sources of variation. Therefore, in the cases of C_x, C_z, C_y, C, TX, and TZ, the amount of variation accounted for by a relatively few sources needs to be considered in this light.

Considering C_x, 75.71 percent of the total variation is accounted for by the first 7 sources, and 13.42 percent of the total variation is accounted for by Errors #2 and #4. If 13.42 were subtracted from the total variation (100 percent), 86.58 percent would remain. Considering the 86.58 percent as being a closer estimate of the amount available for treatment effects, then 75.71 could be divided by 86.58

to give an adjusted value of 87.45 percent. The 87.45 percent value better indicates that 7 sources account for a relatively large percent of the available variation. Likewise with C_z, 6 sources account for 64.44 percent of the total variation. However, the 64.44 yields an adjusted value of 81.84 percent.

In the cases of C_y, C, TX, and TZ, Error #2 is not available as a suitable error term. However, an adjustment can be made for Error #4. For C_y, 40.02 percent of the total variation is accounted for by 8 sources. The 40.02 yields an adjusted value of 59.61 percent. For C, 40.42 percent is accounted for by 8 sources. The 40.42 yields an adjusted value of 60.58 percent. For TX, 36.04 percent is accounted for by 7 sources. The 36.04 yields an adjusted value of 56.56 percent. For TZ, 29.88 percent is accounted for by 6 sources. The 29.88 yields an adjusted value of 49.25 percent.

The adjusted percentage values for C_x, C_z, C_y, C, TX, and TZ indicate that although the amounts of variation accounted for by a few sources may not be as great as with F_x, F_y, F_z, and F; nevertheless, large amounts of the available variation are accounted for by a small number of sources.

Table XII allows comparisons to be readily made between sum of squares partitionings for the various dependent factors. Considering all of the dependent factors together, it can be seen from Table XII that α, y, and β_d account for large amounts of the total variation.

Table XIII summarizes the building of the prediction equations, and Table XIV presents the prediction equations which were developed. The prediction equations were developed through the use of a stepwise multiple regression computer program (2). With this program, the user chooses which terms he will make available for the stepwise selection by the program, and then the program builds an equation one term at a time. A maximum of 80 terms can be made available to the program in a single run, and any of these terms can be forced to enter an equation. In each step, the program adds the term which will provide the largest increment in the percent of the total variation accounted for by the equation. All independent factors and two factor interaction terms were made available to the program. All products involving a single independent factor and y^2, y^3, or y^4 were made available. In addition, three and four factor interaction terms with large associated sums of squares as indicated by the sum of squares partitionings were also made available. A new variable, $\beta_{d_1} = \beta_d - 90^\circ$, and its appropriate combinations with other variables were also made available to the program.

For each dependent factor, two prediction equations were developed. In each case, the first equation was a simplified one in which some terms were forced into the equation. However, with the second equation, no terms were forced into the equation, but rather the program was allowed to develop the equation without external restriction. After the program had built the equations, these were examined and truncated such that fairly simple equations were obtained which, nonetheless, would account for reasonably large proportions of the total variation.

For each of the 20 equations developed, percent of total variation accounted for by the equation can be considered. However, it is important to examine the sum of squares partitionings as one considers these equations. Some of the equations account for quite a small proportion of the total variation, but the associated sum of squares partitionings, likewise, may lack large sum of squares concentrations.

For some of the dependent factors, it can be seen that both the simplified and the more complex equations account for an adequately large proportion of the total variation. While for other dependent factors, there is considerable difference in the proportions of the total variation accounted for by the two equations.

Terms involving y and y^3 appear frequently in the equations, whereas, terms involving y^2 and y^4 do not. Considering the shapes of the graphs in Figures 19 thru 28, this result would not be unexpected. These graphs consider only the dependent quantities F_x, F_y, and F_z, but graphs associated with other dependent quantities are of similar shape.

Graphs involving selected interference conditions are presented in Figures 19 thru 28. Considering the sum of squares partitionings and prediction equations, it can be noted that terms such as y, y^3, wy, and αy^3 appear frequently. Therefore, it was decided that graphs would be presented illustrating the effects which y has on the dependent factors. It was also desired to illustrate the effects of varying the other independent factors one at a time. The dependent factors F_x, F_y, and F_z were selected for illustration, but similar treatment could be given to the other dependent factors.

For Figures 19 thru 22, the dependent factor is F_y. For Figures 23 thru 25, F_x is the dependent factor. For Figures 26 thru 28, F_z is the dependent factor. In each of these figures, y values are indicated along the abscissa, and values of the dependent factor are indicated along the ordinate. In all figures, the long dashed lines represent a high interference control condition. The curve in solid line is plotted for comparison with the control. In some cases, the curve represented in solid line is shifted upward so that interference effects can be more readily observed. Consider Figure 19. At y = -15", the high interference and low interference curves indicate different values of draft force. For y = -15", the dynamometer tool is operated by itself without the interfering tool being in the soil. The different values indicated by the two curves at y = -15" are due to the different values of the independent quantities V and α. These different values at y = -15" are related to single tool effects, rather than interference effects. Therefore, the low interference curve is shifted upward so that interference effects can be more readily observed.

Figure 19 shows the effects of operating at high interference and low interference conditions. Both curves have the same general shape, but interference is much more pronounced in the one case. For the high interference graph, as y varies, the draft force changes very considerably. At y = -4", the draft force is 42.8 pounds or 51.3 percent above the reference value of 28.3 pounds. At y = +8", the draft force is 19.5 pounds or 31.1 percent below the reference value. At y = +15", the curve does not coincide with the reference line. In general, it cannot be expected that the curve would approach the reference line as y became large (for example, y = +50"), since boundary condition interference would still be occurring. That is, the interfering tool would still be altering the soil surface profile before the soil reached the dynamometer tool.

Figure 20 shows the effects of varying α at high interference. In this figure, the Series #6 curve was shifted upward. With $\alpha = 75^{\circ}$, there is less of an interference effect as compared to the control curve for $\alpha = 105^{\circ}$. A definite αy interaction can be noted between y = -4" and y = +4". At y = -4", an increase in α results in an increase in draft force, whereas, at y = +4", an increase in α results in a decrease in draft force.

Figure 21 illustrates the effects of varying x at high interference. At y = -4", the x = 2.5" curve indicates a lesser interference effect than does the x = 5.5" curve. However, at y = +4", the x = 2.5" curve indicates a greater interference effect. At y = -4", the draft force for the x = 2.5" curve is 36 pounds or 28.6 percent above the reference value of 28 pounds. At y = +4", the draft force for the x = 2.5" curve is 7 pounds or 75 percent below the reference value.

Figure 22 shows the effects of varying d at high interference. The effects are similar to those of varying α. That is, the lower value of d results in less interference with a pronounced dy interaction between y = -4" and y = +4".

For Figures 23 thru 25, the dependent factor is F_x. Figure 23 illustrates the effects of high and low interference conditions. These curves are similar in shape to the curves for draft force. Figure 24 shows the effects of V, and Figure 25 shows the effects of w. These independent factors have similar effects on interference. In each case, the lower value of the independent factor results in less interference. However, the changing of w produces slightly more pronounced effects than changing V.

In Figures 26 thru 28, F_z is the dependent factor. Figure 26 illustrates the effects of high and low interference conditions. Figure 27 shows the effects of β_d, and Figure 28 shows the effects of

β_i. The independent factors β_d and β_i have similar effects on interference with the β_d effects being more pronounced.

Photographs of selected tillage tool tests are presented in Figures 29 thru 41. These photographs deal with some of the same interference conditions as Figures 19 thru 28 and were designed only to show the types and general magnitudes of effects that resulted as the independent factors were varied one at a time. No attempts were made to gather actual quantitative information from these photographs. For each figure, a front view of the tillage system is shown at the left side of the figure and a rear view at the right side of the figure. The front and rear views were not photographed at the same instant of time, but both were photographed while the soil was moving.

The physical effects of interference can be considered in three categories. First, the interfering tool may affect the surface profile of the soil before the soil reaches the dynamometer tool. This effect could take place either with simultaneous or boundary condition interference. Second, the interfering tool may alter the velocity pattern (magnitude and/or direction) of the soil near the dynamometer tool. This effect would only be associated with simultaneous interference. Finally, the interfering tool could alter the physical properties (density, strength, etc.) of the soil before the soil reached the dynamometer tool. This effect could be associated with either simultaneous or boundary condition interference. However, this final effect of interference was generally inoperative for this experimental program, since the soil was uncompacted in its initial condition. In discussion of the photographs, comments will be made about the effects of changing the soil surface profile, rather than about the effects of changing the velocity of the soil. The velocity effects may be equally as important, but they cannot be as readily observed in these single frames.

Figure 29 shows a reference condition without interference. In this case, the dynamometer tool is operated by itself without the interfering tool being in the soil. Consider the curves composed of long dashed lines in Figures 19 thru 28. Figure 29 shows the experimental setup associated with y = -15" for Figures 19 thru 28.

Figures 30 thru 33 show the effects as y assumes values of -4", +4", +8", and +15", respectively. Figures 29 thru 33 correspond to moving along the high interference lines from left to right in Figures 19 thru 28. In Figures 30 thru 33, the superimposed dashed lines are used to represent the flow pattern from Figure 29, reference condition without interference. The data blocks associated with the figures show the interference effects on F_x, F_y, and F_z. The sign conventions for F_x, F_y, and F_z are the same as used previously: F_x is positive to the left in the front view; F_y is positive in the direction of soil velocity V; and F_z is positive downward ($-F_z$ is positive upward). At y = -4", the flow of soil around the dynamometer tool is more impeded as compared to the reference condition. With y = -4", a larger amount of soil accumulates in front of the dynamometer tool. As would be expected, all the forces are larger with the interfering tool at y = -4" as compared to the reference condition.

In Figures 31, 32, and 33 with y = +4", y = +8", and y = +15", respectively, the forces are lower as compared to those for the reference condition. This lowering of forces appears to be due, at least partly, to the formation of a trench behind the interfering tool.

This trench allows a less impeded flow of soil around the dynamometer tool.

Figures 34 thru 40 show the effects of varying the independent factors one at a time. In these figures, the superimposed dashed lines are used to represent the flow pattern from Figure 32, control condition for high interference. Figures 34 thru 40 each correspond to the value y = +8" for the solid line curves in the appropriate figures. That is, Figure 34 is associated with Figure 24 (Effects of V), Figure 35 is associated with Figure 25 (Effects of w), etc. For Figures 34, 36, and 37, the values in column II of the data blocks were adjusted upward in the same manner as were the curves in Figures 24 and 20.

The data blocks associated with Figures 34, 35, 36, and 40 indicate that for the lower values of V, w, α and d, the forces on the dynamometer tool are generally increased as compared to the values for the control condition. This effect is due, at least in part, to the forming of a smaller trench behind the interfering tool for each of these cases.

In Figure 37, with $\beta_d = 105^\circ$, the dynamometer tool isn't able to as well utilize the trench behind the interfering tool, since at $\beta_d = 105^\circ$ the dynamometer tool is directing more soil away from the trench as compared to the control condition with $\beta_d = 75^\circ$.

In Figure 38, with $\beta_i = 75^\circ$, the trench behind the interfering tool is relatively unchanged, but the interfering tool is directing more soil away from the dynamometer tool as compared to the control condition with $\beta_i = 105^\circ$.

In Figure 39, with x = 2.5", the dynamometer tool is, to a greater extent, operating in the trench behind the interfering tool.

Therefore, for x = 2.5", the forces on the dynamometer tool are generally decreased as compared to the values for the control condition.

Figure 41 shows a low interference condition. As indicated by the forces in the data block, the interfering tool was having very little effect on the dynamometer tool forces.

Figure 42 shows the effects that bin side interference has on the operation of a tillage tool. In conducting the factorial program, it was found that a certain amount of interference with the bin side nearest the interfering tool did arise, but its extent was limited enough that it did not greatly affect the values of the dependent factors. This bin side interference was a secondary type, since it occurred on the side nearest the interfering tool. If the bin side interference had occurred at the opposite bin side, its effects would have been more pronounced, since it could have had direct effects on the dependent factors. The exact extent to which the bin side interference affected the dependent factors could not be determined with available equipment, but an attempt was made to gain some information about the magnitude of its effects. Figure 42a shows a condition in which bin side interference was just beginning to affect the draft force on the tillage tool. Figure 42b shows a condition in which the bin side is affecting the draft force to an extent of 2 pounds. The bin side interference did not measurably affect the other forces on the tillage tool. The superimposed dashed lines in Figure 42 are used to represent the flow pattern from Figure 29, reference condition without interference. Figure 30 shows one of the most severe bin side interference conditions which occurred in the factorial program.

Figures 43, 44, and 45 show photographs of soil bodies that formed on the tillage tools. These soil bodies were quite fragile when the tools were removed from the soil, and therefore, portions of the soil bodies often broke away. However, from these photographs, differences in soil body size and shape as influenced by α and β can be seen. Soil bodies, as such, were not studied in this experimental program. These photographs were included, however, as general information to give some indications of the sizes and shapes of soil bodies formed for the conditions of this investigation.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND SUGGESTIONS FOR FUTURE WORK

Summary

The research undertaken in connection with this thesis was related to the general problem of minimizing the amount of energy required to till the soil, consistent with achieving a desired soil condition. The specific problem chosen, involved a soil bin study of three-dimensional interference between two flat plate tillage tools operating in an artificial soil.

The general objective of the investigation was to study and characterize selected aspects of interference between tillage tools.

For the tillage system selected for study, the following were the specific objectives of the investigation:

1. For each dependent quantity (F_x, F_y, F_z, F, C_x, C_y, C_z, C, TX and TZ), determine the percent of the total variation of the dependent quantity that can be attributed to each source of variation (V, w, α, β_d, β_i, x, y, d, and their interactions).
2. For each dependent quantity, develop a prediction equation which relates the dependent and the independent quantities. Each prediction equation should be fairly simple, yet account for a reasonably large percent of the total variation of the

dependent quantity.

3. Display characterization of interference by use of graphic representations.

Experiments were organized in a factorial arrangement and were conducted using a continuous linear soil bin. The forces which the soil exerted on the dynamometer tool were measured, while the interfering tool was positioned at various locations in the vicinity of the dynamometer tool. The independent factors were soil velocity V, width of interfering tool w, orientation of tools (α, β_d, and β_i), and position of interfering tool (x, y, d). The dependent factors were those involved in specifying the wrench which the soil applied to the dynamometer tool (F_x, F_y, F_z, F, C_x, C_y, C_z, C, TX, and TZ).

The data in terms of the values of the independent and dependent variables was analyzed by partitioning sum of squares, conducting F tests on mean squares, developing prediction equations using stepwise multiple regression, and by drawing graphs involving certain variables. In addition, photographs were presented of the tillage tools operating in several different interference conditions.

For some dependent quantities, the associated sum of squares partitionings indicated large concentrations of sums of squares, whereas, for other dependent quantities, the sum of squares were more widely distributed over the sources of variation.

Considering the sums of squares distributions, at least one adequate prediction equation was obtained for each dependent quantity. For some dependent quantities, it was possible to develop a prediction equation of 4 terms which would account for almost 90 percent of the total variation. However, with other dependent quantities, a prediction equation containing 7 terms accounted for less than 30 percent of the total variation.

The objectives of the research program were fulfilled in that interference between tillage tools for the specified tillage system was studied and characterized. The interference was characterized in a definite quantitative manner by indicating the amounts of variation that could be attributed to the various main effects and interactions, and also by developing prediction equations which define relationships between the independent and dependent quantities. In addition, the types and magnitudes of effects caused by interference were characterized in a general manner through presentation of the graphs and photographs associated with certain tillage tool tests.

Conclusions

For the tillage system studied, the conclusions were:

1. For each dependent quantity, a relatively large proportion of the total variation can be accounted for by a relatively few sources of variation. However, Tables II thru XI indicate that considerably larger proportions of the total variation are accounted for by a relatively few sources for F_x, F_y, F_z, and F, as compared to C_x, C_z, C_y, C, TX, and TZ.
2. Considering the sums of squares distributions, at least one adequate prediction equation was obtained for each dependent quantity. These prediction equations, given in Table XIV, relate the independent and dependent quantities.
3. Interference can have very large effects on tillage tool forces. For example, consider Figure 21. With x = 5.5" and

$y = -4''$, the draft force on the dynamometer tool was 42.8 pounds or 52.8 percent above the reference value of 28.0 pounds without interference. With $x = 2.5''$ and $y = +4''$, the draft force was 7.0 pounds or 75.0 percent below the reference value.

4. Many of the effects caused by interference can be observed in soil flow pattern differences as indicated in Figures 29 thru 41.

Suggestions for Future Work

In preliminary studies associated with this research, attempts were made to compact the soil before it reached the test area. A soil density increase of only 5 pounds per cubic foot was achieved, and therefore, an uncompacted soil was used in the main experimental program. However, additional attempts should be made to compact the soil in a feasible manner. There are at least two reasons for compacting the soil. First, the soil initial density could be expected to have some effects on the interference patterns between the tillage tools. Second, if a high enough initial soil density could be obtained, it might be possible to determine the volume of soil that was disturbed by the tillage tools. Then, the amount of soil disturbed could be related to the independent factors.

In this study, the independent factors were V, w, α, β_d, β_i, x, y, and d. D and W were held constant. Additional information could be obtained about interference through concentrated study with x, y, d, and D being the independent factors. The other quantities could be held constant as follows: $V = 2$ fps, $w = W = 3''$, $\alpha = 90^o$, $\beta_d = 90^o$,

$\beta_i = 90^o$. As discussed in Chapter III, the roles of the two tools are, in effect, switched as y changes from positive to negative values. By considering positive values of x, positive and negative values of y, and varying d and D, it would be possible to obtain complete information about the forces on both tools, even though only one would be instrumented.

A SELECTED BIBLIOGRAPHY

(1) Barnes, K. K., C. W. Bockhop, and H. E. McLeod. "Similitude in Studies of Tillage Implement Forces." Agricultural Engineering, Vol. 41 (1960), 32-7, 42.

(2) BMD Biomedical Computer Programs. Edited by W. J. Dixon. Berkeley and Los Angeles: University of California Press, 1968.

(3) Bockhop, C. W., W. G. Lovely, and R. L. Schafer. "Prototype Studies of Tillage Implements." Transactions of the American Society of Agricultural Engineers, Vol. 11 (1968), 661-4.

(4) Cohron, G. T. "Model Testing of Earthmoving Equipment." American Society of Agricultural Engineers, Paper No. 61-113, presented at Ames, Iowa, June, 1961.

(5) Gill, William R. and Glen E. Vanden Berg. Soil Dynamics in Tillage and Traction. Washington, D. C.: U. S. Government Printing Office, 1967.

(6) Hanomoto, B. "Artificial Soils for Laboratory Studies in Land Locomotion." Land Locomotion Laboratory, Report No. 20, Army Tank-Automotive Center, Warren, Michigan, November, 1957.

(7) Harrison, W. L., Jr. "Soil Bins and Instrumentation for Research and Engineering Applications." Society of Automotive Engineers, Paper No. 408B, presented at Milwaukee, Wisconsin, September, 1961.

(8) Kaburaki, H. and M. Kisu. "Studies on Cutting Characteristics of Plows." Kanto-Tosan Agricultural Experiment Station Journal, Vol. 12 (1959), 90-114. (National Institute of Agricultural Engineering, English Translation 79.)

(9) Korayem, A. Y. and C. A. Reaves. "Artificial Soils - Frictional Properties and Chisel Tests." American Society of Agricultural Engineers, Paper No. 61-652, presented at Chicago, Illinois, December, 1961.

(10) Myers, H. A. and E. L. Wegscheid. "Soil Bin Instrumentation." Agricultural Engineering, Vol. 48 (1967), 442-45, 463.

(11) Natrella, M. G. Experimental Statistics. Washington, D. C.: U. S. Government Printing Office, 1963.

(12) Payne, P. C. J. "The Relationship Between the Mechanical Properties of Soil and the Performance of Simple Cultivation Implements." Journal of Agricultural Engineering Research, Vol. 1 (1956), 23-50.

(13) Payne, P. C. J. and D. W. Tanner. "The Relationship Between Rake Angle and the Performance of Simple Cultivation Implements." Journal of Agricultural Engineering Research, Vol. 4 (1959), 312-25.

(14) Rathje, J. "The Cutting of Sand." Engineering, Vol. 134 (1932), 116-8.

(15) Reed, I. F. and M. O. Berry. "Tests Comparing Plow Bottoms." National Tillage Machinery Laboratory Annual Report, Auburn, Alabama, 1946.

(16) Rowe, R. J. and K. K. Barnes. "Influence of Speed on Elements of Draft of a Tillage Tool." Transactions of the American Society of Agricultural Engineers, Vol. 4 (1961), 55-7.

(17) Siemens, J. C. and J. A. Weber. "Soil Bin for Model Studies on Tillage Tools and Traction Devices." Journal of Terra Mechanics, Vol. 1 (1964).

(18) Zelenin, A. N. Basic Physics of the Theory of Soil Cutting. Moscow, 1950.

APPENDIX A

SPECIFICATIONS
OF
INSTRUMENTS

SPECIFICATIONS OF RECORDER

The recorder was purchased from Beckman Instruments, Incorporated, 3900 River Road, Schiller Park, Illinois 60176. The recorder had six type R channels and two type RC channels. The type R channels were used with the load cells. The type RC channels were used with the tachometer system and the density measurement system.

TYPE R SPECIFICATIONS

Sensitivity Range: 1 microvolt per mm to 5 volts per mm.

Channel Width: 40 mm.

Input: Input impedance approximately one megohm at highest sensitivity; varies when input attenuator inserted, from minimum of 0.25 meg to maximum of 12.5 meg.

Zero Suppression: More than 500 mm plus and minus; ten-turn Helipot potentiometer available for calibrated zero suppression.

Common Mode: Common mode rejection: Greater than 180 db at DC, with shorted input. Greater than 100 db at 60 cps, with shorted input. Common mode voltage: $\pm$ 250 VDC maximum.

Drift: 1 microvolt per hour equivalent input stylus drift at maximum sensitivity under normal ambient conditions.

Frequency Response: Flat within $\pm$ 1 db from DC to 30 cps at 40 mm deflection; within $\pm$ 1 db from DC to 100 cps at 10 mm deflection.

Rise Time: 7 ms for 10% to 90% of 40 mm. 4 ms for 10% to 90% of 20 mm.

Linearity: ± 0.5% for central 40 mm.

Paper Speeds: An 8 speed precision chart drive provides speeds from 1 to 250 mm/sec. Chart speed accuracy; ± 1%.

Paper Width: 16 inches.

Paper Capacity: 500 feet.

Auxiliary Power Available: 15 volts at 1 ampere, regulated for strain gage excitation.

Power Requirements: 115 volts at 60 cps.

TYPE RC SPECIFICATIONS

Sensitivity Range: 1 mv per mm to 5 volts per mm.

Input: Single-ended. Input impedance; 1 megohm minimum at 2 mv per mm and higher, 0.5 megohm minimum at 1 mv per mm.

Zero Suppression: 120 mm, plus and minus; ten-turn Helipot potentiometer available for calibrated suppression.

Drift: With low impedance source, 0.2 mv equivalent input per hour at maximum gain under normal ambient conditions; source resistance will increase drift approximately 0.005 mv per thousand ohms.

Frequency Response: Flat within ± 1 db from DC to 30 cps at 40 mm deflection; within ± 1 db from DC to 100 cps at 10 mm deflection.

Rise Time: 7 ms for 10% to 90% of 40 mm. 4 ms for 10% to 90% of 20 mm.

Linearity: ± 0.5% for central 40 mm.

Calibration: Internal for each channel.

SPECIFICATIONS OF LOAD CELLS

The six load cells were purchased from Transducers, Incorporated, 11971 East Rivera Road, Santa Fe Springs, California 90670. These load cells were of the bonded strain gage type. In each load cell, 4 strain gages formed a full Wheatstone bridge, to produce an electrical output signal which was directly proportional to applied force.

<u>Non-linearity (Terminal Method)</u>: 0.20% full scale tension and compression

<u>Hysteresis (Unidirectional)</u>: 0.10% full scale

<u>Sensitivity</u>: 3 mv/v at rated capacity

<u>Accuracy of Full Scale Output</u>: ± 5% tension or compression

<u>Zero Balance</u>: ± 5% full scale

<u>Input and Output Resistance (350 ohms standard)</u>: ± 10% tolerance

<u>Temperature Effect on Zero Balance</u>: less than 0.02% full scale per ^{o}F

<u>Temperature Effect on Output</u>: less than 0.02% of load per ^{o}F

<u>Temperature Range (compensated)</u>: 15 to 150^{o}F

<u>Maximum Safe Temperature</u>: 250^{o}F

<u>Excitation Voltage Recommended</u>: 10 volts, DC or AC

<u>Maximum Excitation Voltage</u>: 18 volts, DC or AC

<u>Maximum Safe Overload</u>: 150% rated capacity

<u>Ultimate Overload Rating</u>: 200% rated capacity

<u>Side Load Effect (1° off axis)</u>: less than 0.25% full scale

<u>Side Load Effect (3° off axis)</u>: less than 0.50% full scale

<u>Standard Temperature for Specifications</u>: 77°F

SPECIFICATIONS OF DENSITY MEASUREMENT SYSTEM

A density measurement system was used for measuring the soil density shortly before the soil reached the test area. This system consisted of a radioactive source, a radiation detector, a meter, and channel 8 of the 8-channel recorder. The source, detector, and meter were purchased from Texas Nuclear, P.O. Box 9267, Austin, Texas 78756.

The radioactive source was 2 curies of cesium 137. In operation of the density measurement system, a shutter in the source housing was opened and radiation was allowed to pass through the soil to the detector. The amount of radiation received by the detector was inversely related to the density of the soil. A current was developed in the detector, and this current was directly proportional to the radiation received. The electrical signal from the detector was then conditioned and was available at the meter and on channel 8 of the 8-channel recorder. Detailed specifications (rise time, drift, etc.) of the source-detector-meter sub-system were not supplied by the manufacturer.

The specifications for channel 8 of the recorder are given in the Specifications of the Recorder.

SPECIFICATIONS OF TACHOMETER SYSTEM

A tachometer system was used to measure the linear speed of the test belt. This system consisted of a DC tachometer generator, a tachometer voltmeter, and channel 7 of the 8-channel recorder.

The generator and voltmeter were calibrated as a sub-system at the factory. This sub-system was purchased from Servo-tek Products Company, Incorporated, 1086 Goffle Road, Hawthorne, New Jersey. The sub-system was calibrated so as to have a maximum error of 1% of the full scale reading. The sub-system was temperature compensated and calibrated at 25°C. The sub-system accuracy was not affected by more than 1/2% of full scale for either an increase or decrease of 50°C. The full scale meter reading was 1000 rpm, but the generator shaft was fitted with a driving disk of appropriate size so that 1000 rpm of the generator shaft was equal to 10 ft/sec belt speed. The generator output was 7 volts per 1000 rpm.

The specifications of channel 7 of the recorder are given in the Specifications of the Recorder.

APPENDIX B

ORIGINAL DATA

EXPLANATORY INFORMATION FOR ORIGINAL DATA

The main factorial experimental program was organized as 32 series. The data from each series is presented on a separate page. This original data is identified as Series 1 thru 32.

An explanation of the information presented on each sheet of original data will now be given. First, the series is identified. Next, the specified values of the independent quantities V, w, α, β_d, and β_i are given. Before the dynamometer tool was lowered into the soil, one observation of load cell forces was taken; this information appears in the first row that is identified by "ZERO". The sign conventions for the load cell forces are as given in Figure 2. The dynamometer tool was then lowered into the soil and observations were made without the interfering tool being in the soil; the information from these observations appears in the first row that is identified by "STANDARD". The measured value of soil density, the measured value of soil velocity, and two observations of load cell forces were recorded. The next 20 tests were conducted at the various required values of x, y, and d. After these 20 tests had been completed, another standard test and another zero test were carried out.

In order to calculate the dependent quantities TX and TZ, it was necessary to specify the location and orientation of the dynamometer tool. This location and orientation were specified with respect to the origin of coordinates given in Figure 2. The location of the center of the front bottom edge of the tool was given by P(r, s, t), with r being positive to the left when looking in the direction of soil flow, s being positive in the direction of soil flow, and t being positive downward. The orientation of the dynamometer tool was specified by the equation of the plane which contained the front surface of the tool.

For $\alpha = 75^\circ$, the calculated coordinates of P were

$$(-0.115, -11.083, 21.316)$$

For $\alpha = 105^\circ$, the calculated coordinates of P were

$$(-0.115, -1.001, 21.316)$$

For $\alpha = 75^\circ$ and $\beta_d = 75^\circ$, the equation of the plane was

$$-0.04955r - 0.18512s - 0.04961t = 1$$

For $\alpha = 75^\circ$ and $\beta_d = 105^\circ$, the equation of the plane was

$$0.05012r - 0.18726s - 0.05018t = 1$$

For $\alpha = 105^\circ$ and $\beta_d = 75^\circ$, the equation of the plane was

$$-0.03969r - 0.14828s + 0.03974t = 1$$

For $\alpha = 105^\circ$ and $\beta_d = 105^\circ$, the equation of the plane was

$$0.04006r - 0.14965s + 0.04010t = 1$$

SERIES 1

V SET	W INT	ALPHA	B DYN	B INT
3	2	75	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						-0.2		0.0		0.0		-0.2		0.2		0.0	
STANDARD				78.2	2.9	2.3	2.3	17.5	17.0	-15.0	-15.0	-22.5	-22.0	-5.0	-5.0	6.0	6.0
1 1	5.5	-4.0	4.0	77.9	3.0	2.0	2.0	18.0	18.5	-17.0	-17.0	-23.5	-23.5	-4.5	-4.5	5.5	5.5
1 2	2.5	4.0	4.0	77.8	3.0	3.5	3.5	12.5	12.5	-9.5	-9.5	-18.0	-18.0	-7.0	-7.0	8.0	8.0
1 3	2.5	15.0	4.0	77.8	3.0	2.3	2.3	16.0	16.0	-14.0	-14.0	-20.5	-20.5	-5.0	-5.0	6.0	6.0
1 4	5.5	-4.0	6.0	77.8	3.0	1.5	1.5	19.5	19.5	-18.0	-18.0	-23.5	-23.5	-3.5	-3.5	5.0	5.0
1 5	5.5	8.0	4.0	77.8	3.0	2.4	2.4	15.5	15.5	-13.0	-13.0	-20.5	-20.5	-5.0	-5.0	6.5	6.5
1 6	5.5	15.0	4.0	77.8	3.0	2.0	2.0	16.5	16.5	-14.5	-14.5	-21.5	-21.5	-5.0	-5.0	6.0	6.0
1 7	5.5	-15.0	6.0	77.8	3.0	2.0	2.0	17.0	17.0	-15.0	-15.0	-21.5	-21.5	-4.5	-4.5	5.5	5.5
1 8	5.5	15.0	6.0	77.8	3.0	2.0	2.0	15.5	16.0	-14.0	-14.5	-20.5	-21.0	-4.5	-5.0	6.0	6.5
1 9	2.5	-4.0	6.0	77.8	3.0	1.2	1.3	18.0	18.0	-17.5	-17.5	-22.5	-22.5	-2.5	-2.5	4.5	4.5
1 10	2.5	8.0	4.0	77.8	3.0	2.4	2.4	14.5	14.5	-12.0	-12.0	-19.5	-19.5	-5.0	-5.0	6.0	6.5
1 11	5.5	4.0	6.0	77.8	3.0	3.5	3.5	16.0	16.0	-12.5	-12.5	-22.5	-22.5	-7.5	-7.5	8.5	8.5
1 12	5.5	8.0	6.0	77.8	3.0	2.8	2.8	15.0	15.0	-12.5	-12.5	-20.0	-20.0	-5.5	-5.5	7.0	7.0
1 13	2.5	-15.0	6.0	77.8	3.0	2.0	2.0	17.0	17.0	-15.0	-15.0	-22.0	-22.0	-4.5	-4.5	5.5	5.5
1 14	5.5	4.0	4.0	77.8	3.0	3.0	3.0	16.5	16.5	-14.0	-14.0	-22.5	-22.5	-6.5	-6.5	7.5	7.5
1 15	2.5	4.0	6.0	77.8	3.0	3.7	3.7	10.0	10.0	-7.0	-7.0	-15.5	-15.5	-7.5	-7.5	7.5	7.5
1 16	2.5	-4.0	4.0	77.8	3.0	2.0	2.0	18.0	18.0	-16.5	-16.5	-22.5	-22.5	-4.0	-4.0	5.0	5.0
1 17	2.5	8.0	6.0	77.8	2.9	3.0	3.0	13.0	13.0	-10.0	-10.0	-18.0	-18.0	-6.0	-6.0	7.5	7.5
1 18	2.5	-15.0	4.0	77.8	3.0	2.0	2.0	17.0	17.0	-15.0	-15.0	-21.5	-21.0	-4.5	-4.5	5.0	5.0
1 19	2.5	15.0	6.0	77.8	2.9	2.4	2.4	15.5	15.5	-13.0	-13.0	-20.0	-20.0	-5.0	-5.0	6.0	6.0
1 20	5.5	-15.0	4.0	77.8	3.0	2.0	2.0	17.5	17.5	-15.0	-15.0	-22.0	-22.0	-5.0	-5.0	5.5	5.5
STANDARD				77.8	3.0	2.0	2.0	17.5	17.5	-15.0	-15.0	-22.0	-22.0	-5.0	-5.0	5.5	5.5
ZERO						-0.2		0.0		0.0		-0.2		0.0		0.1	

SERIES 2

V SET	W INT	ALPHA	B DYN	B INT
1	4	75	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.4	1.0	1.8	1.8	15.5	15.5	-13.0	-13.0	-19.5	-19.5	-5.0	-5.0	5.5	5.5
2 1	5.5	-4.0	6.0	78.6	1.0	-0.9	1.1	20.0	20.0	-19.0	-19.5	-22.5	-22.5	-2.0	-2.0	3.0	2.5
2 2	2.5	15.0	4.0	78.8	1.0	2.0	2.0	15.0	15.0	-12.5	-12.5	-19.0	-18.5	-5.0	-5.0	6.5	6.5
2 3	2.5	-4.0	6.0	78.5	1.0	-1.0	-1.0	17.5	18.0	-19.0	-18.5	-19.5	-19.5	0.5	0.5	1.5	1.5
2 4	5.5	4.0	6.0	78.6	1.0	4.0	4.0	14.5	14.5	-10.0	-9.5	-20.0	-19.5	-9.0	-9.0	9.5	9.5
2 5	5.5	4.0	4.0	78.5	1.0	3.0	3.0	15.0	15.0	-11.0	-11.0	-20.0	-19.5	-7.5	-7.5	8.0	8.0
2 6	5.5	-15.0	4.0	78.8	1.0	1.8	1.8	15.5	15.5	-13.0	-13.0	-19.0	-19.0	-5.0	-5.0	5.5	5.5
2 7	5.5	-4.0	4.0	78.9	1.0	1.0	0.8	18.0	18.0	-16.5	-16.5	-21.5	-21.0	-3.5	-3.5	4.0	4.5
2 8	5.5	8.0	4.0	78.8	1.0	2.2	2.0	15.0	14.5	-11.5	-11.5	-18.0	-18.0	-6.0	-5.5	6.5	6.5
2 9	2.5	8.0	6.0	78.8	1.0	2.1	2.3	9.5	9.5	-6.0	-6.0	-12.5	-12.5	-5.5	-6.0	6.0	6.5
2 10	2.5	-15.0	4.0	78.8	1.0	1.5	2.0	15.0	15.5	-13.0	-13.0	-19.0	-18.5	-4.5	-4.5	5.0	5.0
2 11	5.5	15.0	6.0	79.0	1.0	2.0	2.0	15.0	15.0	-12.5	-12.5	-19.0	-19.0	-5.0	-5.0	6.0	6.0
2 12	2.5	8.0	4.0	79.0	1.0	2.3	2.2	12.5	12.5	-10.0	-10.0	-16.0	-16.5	-5.5	-5.5	6.5	6.0
2 13	5.5	8.0	6.0	79.0	1.0	2.9	2.8	13.5	13.0	-10.0	-10.0	-17.5	-17.5	-7.0	-7.0	7.5	7.5
2 14	2.5	-15.0	6.0	79.0	1.0	1.8	2.0	15.5	16.0	-13.0	-13.5	-18.5	-19.0	-5.0	-5.0	5.0	5.0
2 15	5.5	-15.0	6.0	79.0	1.0	1.8	1.8	15.5	16.0	-13.0	-13.5	-19.0	-19.0	-5.0	-5.0	5.5	5.0
2 16	5.5	15.0	4.0	79.0	1.0	2.0	2.0	16.0	16.0	-13.0	-13.0	-19.0	-19.0	-5.0	-5.0	5.5	5.5
2 17	2.5	-4.0	4.0	79.0	1.0	0.0	0.1	18.0	18.5	-17.5	-17.0	-20.0	-20.0	-2.0	-2.5	2.5	3.0
2 18	2.5	4.0	6.0	78.8	1.0	2.8	2.8	7.5	7.5	-3.5	-4.0	-10.0	-10.5	-7.0	-7.0	6.0	6.5
2 19	2.5	4.0	4.0	78.7	1.0	3.0	3.0	10.0	10.0	-6.5	-6.5	-14.0	-14.0	-6.5	-7.0	7.5	7.5
2 20	2.5	15.0	6.0	78.7	1.0	2.1	2.2	14.5	14.5	-12.0	-11.5	-18.5	-18.0	-5.5	-5.0	6.5	6.5
STANDARD				78.6	1.0	1.8	1.7	16.0	16.0	-13.5	-14.0	-19.5	-19.0	-4.0	-4.5	5.0	5.5
ZERO						0.0		0.0		0.2		-0.1		-0.1		0.2	

SERIES 3

V SET	W INT	ALPHA	B DYN	B INT
1	2	105	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.5	1.0	-2.8	-2.7	23.0	23.0	-23.5	-23.5	-24.0	-24.5	7.0	7.5	1.0	1.5
3 1	5.5	-4.0	4.0	78.5	1.0	-4.0	-4.0	23.0	22.5	-23.5	-23.5	-24.0	-24.0	7.5	8.0	0.5	0.5
3 2	2.5	-15.0	4.0	78.5	1.0	-3.0	-3.0	22.5	22.5	-24.0	-23.5	-24.5	-24.0	7.5	8.0	-0.3	-0.3
3 3	2.5	-4.0	6.0	78.5	1.0	-5.3	-5.3	26.0	26.5	-27.5	-27.0	-28.5	-28.0	12.5	12.5	-2.5	-2.5
3 4	5.5	8.0	6.0	78.5	1.0	-1.0	-1.5	18.0	17.5	-18.5	-18.0	-19.5	-19.0	3.0	3.0	-2.5	-3.0
3 5	5.5	-4.0	6.0	78.5	1.0	-5.0	-5.3	27.0	27.0	-28.0	-28.5	-29.0	-29.5	12.5	12.0	-1.5	-2.0
3 6	2.5	8.0	6.0	78.5	1.0	-1.0	-1.0	17.0	16.5	-17.0	-17.5	-17.5	-18.5	2.0	2.5	3.0	2.5
3 7	2.5	4.0	4.0	78.5	1.0	-0.5	-0.5	15.0	15.0	-15.5	-15.0	-16.0	-16.5	0.5	0.5	4.0	4.0
3 8	2.5	-4.0	4.0	78.5	1.0	-4.0	-4.0	24.0	24.0	-25.0	-25.5	-26.0	-26.5	10.0	9.5	-0.5	-0.5
3 9	5.5	4.0	4.0	78.5	1.0	-1.0	-1.0	19.5	20.0	-20.0	-20.0	-21.0	-21.0	2.5	2.5	3.5	4.0
3 10	2.5	-15.0	6.0	78.5	1.0	-3.0	-3.0	22.0	22.0	-23.0	-23.0	-24.0	-24.0	7.5	7.5	0.5	0.5
3 11	2.5	8.0	4.0	78.3	1.0	-2.0	-2.0	20.0	19.5	-20.5	-20.0	-21.5	-21.0	5.5	5.0	2.5	2.0
3 12	5.5	8.0	4.0	78.5	1.0	-1.8	-1.8	19.5	19.0	-20.5	-20.0	-21.0	-21.0	4.5	4.5	2.5	2.5
3 13	5.5	-15.0	6.0	78.4	1.0	-2.8	-2.9	22.0	21.5	-23.0	-23.0	-23.5	-24.0	7.0	7.0	1.0	1.5
3 14	5.5	4.0	6.0	78.5	1.0	-0.5	-0.5	17.0	17.0	-17.5	-17.5	-18.5	-18.5	0.5	0.5	4.5	4.5
3 15	5.5	-15.0	4.0	78.5	1.0	-2.8	-2.7	21.5	22.0	-22.5	-22.5	-23.5	-24.0	7.0	7.0	1.0	1.5
3 16	2.5	4.0	6.0	78.5	1.0	0.0	0.5	10.0	10.0	-10.0	-10.5	-11.0	-11.5	-1.0	-1.5	2.5	3.0
3 17	5.5	15.0	4.0	78.5	1.0	-2.6	-2.7	21.5	21.0	-22.5	-22.5	-23.0	-23.0	6.5	6.5	1.0	1.5
3 18	2.5	15.0	6.0	78.5	1.0	-2.8	-3.0	21.5	22.0	-22.5	-23.0	-23.0	-23.5	7.5	7.5	1.0	1.0
3 19	5.5	15.0	6.0	78.5	1.0	-2.5	-2.5	21.5	21.5	-22.5	-22.5	-23.0	-23.0	6.0	6.5	1.5	1.0
3 20	2.5	15.0	4.0	78.5	1.0	-3.0	-3.0	22.5	22.5	-23.5	-23.5	-24.0	-24.0	7.5	7.5	0.5	0.5
STANDARD				79.3	1.0	-3.0	-3.0	22.5	22.5	-23.5	-23.0	-24.0	-23.5	7.5	7.5	0.5	0.5
ZERO						0.0		0.2		0.1		0.0		0.0		0.0	

SERIES 4

V SET	W INT	ALPHA	B DYN	B INT
3	4	75	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		-0.2		0.0		0.0	
STANDARD				78.5	2.9	2.3	2.3	17.5	17.5	-15.0	-15.0	-21.5	-21.0	-5.0	-5.0	6.0	6.0
4 1	2.5	8.0	6.0	78.5	2.8	3.2	3.5	9.0	9.0	-6.0	-6.0	-14.0	-13.5	-6.5	-6.5	7.5	7.5
4 2	5.5	-15.0	6.0	78.3	2.8	2.3	2.3	17.5	17.5	-15.0	-15.0	-22.5	-22.5	-5.0	-5.0	6.0	6.0
4 3	2.5	4.0	6.0	78.3	2.8	3.0	3.0	7.5	7.5	-4.0	-4.0	-11.0	-11.5	-6.0	-6.5	6.0	6.0
4 4	2.5	-15.0	6.0	78.3	2.8	2.3	2.3	17.0	17.5	-15.0	-15.0	-21.5	-21.0	-5.0	-5.0	6.0	6.0
4 5	2.5	8.0	4.0	78.2	2.8	3.0	3.0	12.5	12.5	-9.0	-9.0	-16.5	-16.5	-5.5	-6.0	6.5	6.5
4 6	5.5	4.0	4.0	78.2	2.8	3.5	3.5	15.0	15.5	-11.5	-11.5	-21.0	-21.0	-7.0	-7.0	8.0	8.0
4 7	5.5	15.0	6.0	78.4	2.8	2.5	3.0	15.0	15.0	-12.5	-12.5	-20.0	-20.0	-5.5	-6.0	7.0	7.0
4 8	5.5	-15.0	4.0	78.2	2.8	2.2	2.3	17.5	17.5	-15.0	-15.0	-22.0	-21.5	-5.0	-4.5	6.0	6.0
4 9	2.5	15.0	6.0	78.1	2.8	2.5	2.5	12.5	12.5	-10.0	-10.0	-16.5	-16.5	-5.0	-5.0	6.0	6.5
4 10	5.5	8.0	4.0	78.2	2.8	2.7	2.7	15.0	15.0	-11.5	-12.0	-19.0	-19.5	-5.0	-5.5	7.0	7.0
4 11	5.5	4.0	6.0	78.2	2.8	4.0	4.0	14.5	14.5	-10.5	-10.5	-20.0	-19.5	-8.0	-8.5	9.0	9.0
4 12	2.5	4.0	4.0	78.2	2.8	3.2	3.2	10.0	10.0	-7.5	-7.5	-15.0	-15.0	-6.0	-6.5	7.5	7.5
4 13	5.5	-4.0	6.0	78.2	2.8	0.6	0.7	21.5	21.5	-20.0	-21.0	-25.0	-25.0	-2.0	-2.5	3.5	3.5
4 14	2.5	15.0	4.0	78.0	2.8	2.5	2.5	14.0	14.0	-11.5	-11.5	-18.5	-18.5	-5.0	-5.0	6.0	6.5
4 15	2.5	-4.0	4.0	77.8	2.8	0.5	0.5	19.0	19.5	-18.5	-19.0	-22.5	-22.5	-2.0	-2.0	3.5	3.5
4 16	2.5	-4.0	6.0	77.8	2.9	-0.5	-0.5	20.0	20.0	-21.0	-21.0	-22.5	-22.0	0.5	1.0	1.5	2.0
4 17	2.5	-15.0	4.0	77.8	2.9	2.3	2.3	17.0	17.0	-14.5	-15.0	-21.0	-21.0	-4.5	-5.0	5.5	5.0
4 18	5.5	-4.0	4.0	77.8	2.9	1.5	1.5	20.0	20.0	-18.0	-18.0	-23.5	-24.0	-3.5	-3.5	4.5	4.5
4 19	5.5	15.0	4.0	77.8	3.0	2.5	2.5	16.0	16.0	-13.0	-13.0	-20.0	-20.0	-5.0	-5.0	6.0	6.0
4 20	5.5	8.0	6.0	77.8	3.1	3.5	3.5	13.5	14.0	-10.0	-10.0	-18.5	-19.0	-6.5	-7.0	7.5	8.0
STANDARD				77.8	3.1	2.2	2.3	17.5	17.5	-15.0	-15.0	-21.5	-21.5	-5.0	-5.0	6.0	6.0
ZERO						0.0		0.2		0.0		-0.2		0.0		0.2	

SERIES 5

V SET	W INT	ALPHA	B DYN	B INT
1	2	75	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.2	1.0	2.1	2.2	16.0	16.0	-13.5	-13.5	-19.0	-19.0	-4.5	-4.5	5.0	5.0
5 1	5.5	15.0	6.0	78.2	1.0	2.1	2.1	15.0	15.0	-12.5	-12.5	-18.0	-18.5	-4.0	-4.0	5.0	5.0
5 2	2.5	-4.0	4.0	78.2	1.0	1.3	1.3	17.0	17.0	-15.0	-15.0	-19.0	-19.5	-3.0	-2.5	3.5	3.5
5 3	2.5	-15.0	6.0	78.2	1.0	2.1	2.1	16.0	16.0	-13.5	-13.5	-18.5	-19.0	-4.0	-4.0	5.0	4.5
5 4	5.5	-15.0	4.0	78.4	1.0	2.2	2.2	16.0	16.0	-13.5	-13.5	-19.0	-19.0	-4.5	-4.5	5.0	5.0
5 5	5.5	-15.0	6.0	78.4	1.0	2.2	2.2	16.0	16.0	-13.5	-13.5	-18.5	-19.0	-4.5	-4.5	5.0	5.0
5 6	2.5	15.0	6.0	78.3	1.0	2.0	2.0	15.0	15.0	-12.5	-12.5	-17.5	-17.5	-4.0	-4.0	4.5	4.5
5 7	2.5	15.0	4.0	78.3	1.0	2.1	2.1	15.0	15.0	-12.5	-13.0	-18.0	-18.5	-4.0	-4.0	4.5	4.5
5 8	2.5	4.0	6.0	78.3	1.0	3.6	3.7	10.0	10.0	-6.0	-6.5	-14.0	-14.0	-7.0	-7.0	7.0	7.0
5 9	5.5	8.0	4.0	78.4	1.0	2.2	2.2	14.0	14.0	-12.0	-12.0	-17.5	-17.5	-4.0	-4.0	5.0	5.0
5 10	2.5	-4.0	6.0	78.5	1.0	0.7	0.6	17.5	17.5	-16.5	-16.5	-19.5	-19.5	-1.0	-1.5	2.5	2.5
5 11	5.5	-4.0	6.0	78.5	1.0	1.5	1.5	17.5	17.5	-16.0	-16.5	-21.0	-21.0	-3.0	-3.0	4.0	4.0
5 12	5.5	4.0	4.0	78.5	1.0	2.6	2.6	14.0	14.0	-11.0	-11.5	-17.5	-17.5	-5.0	-5.0	6.0	6.0
5 13	5.5	4.0	6.0	78.5	1.0	3.2	3.2	13.5	13.5	-10.0	-10.0	-17.5	-17.5	-6.0	-6.0	7.0	7.0
5 14	2.5	8.0	6.0	78.5	1.0	3.0	3.0	12.5	12.5	-10.0	-10.0	-16.5	-16.5	-5.0	-5.0	6.0	6.0
5 15	2.5	4.0	4.0	78.6	1.0	3.4	3.4	12.0	12.0	-8.5	-8.5	-16.0	-16.0	-6.0	-6.0	6.5	6.5
5 16	5.5	8.0	6.0	78.5	1.0	2.5	2.5	13.5	13.5	-11.0	-11.0	-16.5	-16.5	-4.5	-4.5	5.0	5.0
5 17	2.5	8.0	4.0	78.5	1.0	2.4	2.4	14.0	13.5	-11.0	-11.5	-16.5	-16.5	-4.0	-4.0	5.0	5.0
5 18	5.5	-4.0	4.0	78.5	1.0	2.0	2.0	17.0	17.0	-14.5	-14.5	-20.0	-20.0	-3.5	-4.0	4.5	4.5
5 19	2.5	-15.0	4.0	78.5	1.0	2.2	2.2	16.0	16.0	-13.0	-13.0	-18.5	-18.5	-4.0	-4.0	4.5	4.5
5 20	5.5	15.0	4.0	78.5	1.0	2.3	2.3	15.0	15.0	-12.5	-12.5	-18.0	-17.5	-4.5	-4.5	5.0	5.0
STANDARD				78.5	1.0	2.3	2.3	16.0	16.0	-13.0	-13.0	-18.5	-19.0	-4.5	-4.5	5.0	5.0
ZERO						0.5		0.3		0.3		0.0		0.0		0.0	

SERIES 6

V SET	W INT	ALPHA	B DYN	B INT
3	4	75	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.0	3.0	-3.0	-3.0	17.5	18.0	-21.0	-21.5	-16.5	-17.0	4.0	4.0	-3.5	-3.5
6 1	2.5	-4.0	4.0	78.0	3.0	-5.0	-5.0	21.0	21.0	-25.5	-25.5	-18.5	-19.0	7.5	7.5	-5.5	-5.5
6 2	5.5	8.0	6.0	78.0	3.0	-0.4	-0.3	13.8	14.0	-13.8	-14.0	-15.0	-15.0	-1.5	-1.5	1.3	1.5
6 3	2.5	8.0	6.0	78.0	3.0	-0.2	-0.2	8.0	8.0	-8.0	-8.0	-9.5	-9.5	-1.5	-1.5	1.5	1.5
6 4	2.5	8.0	4.0	78.0	3.0	-1.5	-1.5	12.0	12.0	-13.5	-14.0	-12.5	-12.5	1.0	1.0	-0.5	-0.5
6 5	2.5	15.0	4.0	78.0	3.0	-2.3	-2.3	14.5	14.5	-17.5	-17.5	-15.0	-15.0	2.5	2.5	-1.5	-1.5
6 6	5.5	4.0	6.0	78.0	3.0	-0.5	-0.5	14.0	14.0	-15.0	-15.0	-16.0	-16.0	-1.5	-1.5	1.0	1.3
6 7	5.5	-4.0	6.0	78.0	3.0	-7.2	-7.5	24.5	24.5	-33.0	-33.0	-22.0	-22.0	11.5	11.5	-8.5	-8.5
6 8	5.5	-15.0	6.0	78.0	3.0	-3.3	-3.3	17.5	17.5	-21.5	-21.5	-17.5	-17.5	4.0	4.0	-2.5	-2.5
6 9	5.5	-15.0	4.0	78.0	3.0	-3.3	-3.3	17.5	17.5	-22.0	-22.0	-17.5	-17.5	4.0	4.0	-2.5	-2.5
6 10	5.5	15.0	4.0	78.0	3.0	-2.4	-2.4	16.5	16.5	-19.5	-19.5	-17.5	-17.5	2.5	2.5	-1.0	-1.0
6 11	2.5	-15.0	4.0	78.0	3.0	-3.5	-3.5	17.5	17.5	-21.5	-21.5	-17.5	-17.5	4.5	4.5	-3.5	-3.0
6 12	5.5	-4.0	4.0	78.0	3.0	-5.5	-5.5	23.5	23.0	-30.0	-29.0	-21.5	-21.5	8.5	8.5	-6.0	-6.0
6 13	5.5	8.0	4.0	78.0	3.0	-1.5	-1.5	15.5	15.5	-17.5	-17.5	-16.5	-16.5	1.0	1.0	0.0	0.0
6 14	5.5	4.0	4.0	78.0	3.0	-1.0	-1.0	15.5	15.5	-17.0	-16.5	-17.0	-16.5	-0.5	-0.5	0.5	0.5
6 15	2.5	4.0	6.0	78.0	3.0	-0.2	-0.2	5.0	5.0	-5.0	-5.0	-6.0	-6.5	-1.5	-1.5	1.0	1.5
6 16	5.5	15.0	6.0	78.0	3.0	-1.7	-1.7	15.5	15.5	-17.5	-17.5	-16.5	-16.5	1.5	1.5	-0.5	-0.5
6 17	2.5	4.0	4.0	78.0	3.0	-0.5	-0.5	8.5	8.5	-9.0	-9.0	-10.0	-10.0	-1.0	-1.0	1.0	1.0
6 18	2.5	-4.0	6.0	78.0	3.0	-6.5	-6.7	21.5	21.5	-29.0	-29.0	-19.5	-19.5	11.0	11.0	-7.5	-7.5
6 19	2.5	-15.0	6.0	78.0	3.0	-3.4	-3.4	17.5	17.5	-21.5	-21.0	-17.0	-16.5	4.5	4.5	-3.0	-3.0
6 20	2.5	15.0	6.0	78.0	3.0	-2.0	-2.0	12.0	12.0	-14.0	-14.0	-12.0	-12.0	2.0	2.0	-1.0	-1.0
STANDARD				78.0	3.0	-3.5	-3.5	18.0	18.0	-21.5	-21.5	-17.0	-17.0	4.5	4.5	-3.5	-3.5
ZERO						0.5		0.0		0.5		0.5		-0.5		-0.2	

SERIES 7

V SET	W INT	ALPHA	B DYN	B INT
3	4	105	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.8	3.0	-3.3	-3.3	25.0	25.0	-26.5	-26.5	-26.5	-26.5	9.0	9.0	0.5	0.5
7 1	5.5	15.0	6.0	78.8	3.0	-1.2	-1.2	20.5	20.5	-21.5	-21.5	-21.5	-21.5	4.5	4.5	3.5	3.5
7 2	2.5	15.0	4.0	78.8	3.0	-2.0	-2.0	21.0	21.0	-22.5	-22.5	-22.5	-22.5	7.0	7.0	1.5	1.5
7 3	5.5	15.0	4.0	78.8	3.0	-1.8	-1.8	21.5	21.5	-23.5	-23.5	-23.5	-23.5	6.0	6.5	2.5	2.5
7 4	2.5	8.0	6.0	78.8	3.0	0.5	0.5	11.0	10.5	-11.0	-11.0	-11.0	-11.0	0.5	0.5	3.5	3.5
7 5	5.5	8.0	4.0	78.8	3.0	-0.6	-0.6	19.0	19.0	-20.5	-20.5	-20.5	-20.5	3.5	3.5	3.5	3.5
7 6	5.5	-4.0	4.0	78.8	3.0	-5.6	-5.7	31.0	31.0	-33.0	-33.0	-33.5	-33.5	14.0	14.0	-1.5	-1.5
7 7	2.5	-15.0	6.0	78.6	3.0	-3.4	-3.4	24.0	25.0	-25.5	-26.5	-25.5	-26.5	9.0	9.0	0.0	0.0
7 8	5.5	4.0	6.0	78.5	3.0	0.3	0.2	16.0	16.0	-16.5	-16.5	-16.5	-16.5	0.2	0.4	3.5	3.5
7 9	5.5	-4.0	6.0	78.5	3.0	-8.4	-8.3	33.5	33.5	-36.5	-36.5	-36.5	-36.5	19.0	19.0	-5.0	-5.0
7 10	2.5	4.0	6.0	78.5	3.0	0.2	0.2	6.0	6.5	-6.5	-7.0	-6.5	-6.5	0.5	0.5	1.5	1.5
7 11	2.5	15.0	6.0	78.5	3.0	-1.3	-1.4	16.5	17.0	-18.0	-18.5	-18.0	-18.5	5.0	5.0	2.0	2.0
7 12	2.5	-4.0	6.0	78.5	3.0	-6.5	-6.5	29.0	29.5	-31.5	-31.5	-31.5	-31.5	16.0	16.0	-3.5	-3.5
7 13	2.5	-15.0	4.0	78.3	3.0	-3.4	-3.4	23.5	23.5	-24.5	-24.5	-24.0	-24.0	9.0	9.0	-0.5	-0.5
7 14	5.5	8.0	6.0	78.4	3.0	0.3	0.3	16.0	16.0	-17.0	-17.0	-17.0	-17.0	1.0	1.0	3.5	4.0
7 15	5.5	4.0	4.0	78.4	3.0	-0.4	-0.4	19.0	18.5	-20.0	-20.0	-20.0	-20.0	2.5	2.5	3.5	3.5
7 16	5.5	-15.0	6.0	78.3	3.0	-3.2	-3.2	24.0	23.5	-25.0	-25.0	-25.0	-25.0	8.5	8.5	0.2	0.3
7 17	2.5	-4.0	4.0	78.0	3.0	-5.0	-5.0	26.5	26.5	-28.5	-28.5	-28.5	-28.5	12.0	12.0	-1.5	-1.5
7 18	2.5	4.0	4.0	78.1	3.0	0.2	0.0	11.5	12.0	-12.5	-13.0	-12.5	-12.5	1.0	1.5	2.5	2.5
7 19	5.5	-15.0	4.0	78.2	3.0	-3.2	-3.2	23.5	23.5	-25.5	-25.5	-25.5	-25.5	9.0	9.0	-0.2	0.0
7 20	2.5	8.0	4.0	78.2	3.0	-0.7	-0.7	16.0	16.0	-16.5	-16.5	-16.5	-16.5	4.0	3.5	2.5	2.5
STANDARD				78.2	3.0	-3.4	-3.4	22.5	22.5	-25.0	-24.5	-24.0	-24.0	9.0	9.0	-0.5	-0.2
ZERO						-0.2		0.0		-1.0		0.0		0.0		0.0	

SERIES 8

V SET	W INT	ALPHA	B DYN	B INT
1	2	105	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.7	1.0	2.2	2.2	22.0	22.0	-22.5	-22.0	-24.0	-24.0	-1.0	-1.5	9.0	9.0
8 1	2.5	8.0	6.0	78.6	1.0	3.4	3.5	17.0	17.0	-16.5	-16.5	-18.5	-18.5	-4.0	-4.0	9.5	9.0
8 2	5.5	4.0	6.0	78.6	1.0	4.5	4.5	18.5	18.5	-17.5	-17.5	-20.0	-20.0	-6.0	-6.0	11.5	11.5
8 3	2.5	-15.0	4.0	78.8	1.0	2.4	2.4	22.0	22.0	-21.5	-21.5	-24.0	-24.0	-1.5	-1.5	9.0	9.0
8 4	2.5	8.0	4.0	78.8	1.0	2.7	2.8	19.0	19.0	-18.5	-19.0	-21.0	-21.0	-2.5	-2.5	9.0	9.0
8 5	2.5	4.0	4.0	78.8	1.0	4.8	4.8	16.5	16.5	-16.0	-16.0	-18.0	-18.0	-6.5	-6.5	11.5	11.5
8 6	5.5	-4.0	4.0	78.8	1.0	1.8	1.8	24.0	24.0	-23.5	-23.5	-26.0	-26.5	-0.5	-0.5	8.5	9.0
8 7	2.5	15.0	6.0	79.4	1.0	2.2	2.2	22.5	22.5	-21.5	-21.5	-24.0	-24.0	-1.5	-1.0	9.0	9.0
8 8	5.5	8.0	6.0	79.5	1.0	3.2	3.2	18.5	18.5	-17.5	-17.5	-19.5	-19.5	-3.5	-4.0	9.0	9.0
8 9	2.5	-15.0	6.0	79.4	1.0	2.3	2.2	22.5	23.0	-22.0	-22.5	-24.0	-24.0	-1.5	-1.5	9.0	9.0
8 10	2.5	-4.0	6.0	79.1	1.0	0.0	-0.3	25.0	25.5	-24.5	-25.0	-26.5	-27.0	3.5	3.5	5.0	6.0
8 11	5.5	15.0	4.0	79.0	1.0	3.0	3.0	21.5	22.0	-21.0	-21.5	-23.5	-24.0	-2.5	-2.5	10.0	10.0
8 12	5.5	15.0	6.0	79.0	1.0	2.9	2.9	21.5	21.5	-21.0	-21.0	-23.5	-23.5	-2.5	-2.5	10.0	10.0
8 13	5.5	4.0	4.0	79.0	1.0	4.0	4.0	20.0	20.0	-19.0	-19.0	-21.5	-21.5	-5.0	-5.0	11.5	11.0
8 14	2.5	15.0	4.0	79.0	1.0	2.0	2.0	22.5	22.0	-21.5	-21.5	-24.0	-24.0	-1.5	-1.5	9.0	9.0
8 15	2.5	-4.0	4.0	79.0	1.0	1.0	1.0	24.0	24.0	-23.5	-24.0	-26.0	-26.0	1.0	1.0	7.5	7.5
8 16	2.5	4.0	6.0	79.0	1.0	4.6	4.6	12.5	12.5	-11.5	-11.5	-13.5	-13.5	-7.5	-7.5	10.0	10.0
8 17	5.5	-4.0	6.0	79.0	1.0	0.7	0.7	25.5	25.5	-25.0	-25.0	-27.5	-27.5	1.5	1.5	7.5	7.5
8 18	5.5	-15.0	4.0	79.0	1.0	2.6	2.6	22.5	22.5	-22.0	-22.0	-24.0	-24.0	-2.0	-2.0	9.5	9.5
8 19	5.5	8.0	4.0	79.0	1.0	3.0	3.0	20.0	20.0	-19.0	-19.0	-21.0	-21.5	-3.0	-3.0	10.0	10.0
8 20	5.5	-15.0	6.0	79.0	1.0	2.7	2.7	22.5	22.5	-21.5	-21.5	-24.0	-24.0	-2.0	-2.0	9.5	9.5
STANDARD				78.9	1.0	2.6	2.6	22.5	22.5	-22.0	-22.0	-24.0	-24.0	-1.5	-1.5	9.0	9.5
ZERO						0.2		0.5		0.2		0.0		-0.5		-0.2	

SERIES 9

V SET	W INT	ALPHA	B DYN	B INT
1	2	105	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				79.3	1.0	-3.0	-3.0	23.5	23.5	-24.5	-24.5	-24.5	-24.5	8.0	8.0	1.0	1.0
9 1	2.5	15.0	6.0	79.4	1.0	-3.3	-3.2	23.0	23.0	-24.0	-23.5	-24.0	-23.5	8.5	8.5	0.5	0.5
9 2	2.5	-4.0	6.0	79.3	1.0	-5.6	-5.6	27.5	27.5	-28.5	-28.5	-29.0	-29.0	13.5	13.5	-2.5	-2.5
9 3	5.5	8.0	6.0	79.6	1.0	-1.3	-1.2	18.5	18.5	-18.5	-18.5	-18.5	-18.5	3.5	4.0	2.0	2.0
9 4	2.5	15.0	4.0	79.5	1.0	-3.2	-3.3	23.5	24.0	-24.0	-24.0	-24.0	-24.0	8.5	8.5	0.0	0.0
9 5	2.5	-4.0	4.0	79.5	1.0	-4.2	-4.2	26.0	26.0	-26.5	-26.0	-27.0	-26.5	10.5	10.5	-1.0	-1.0
9 6	5.5	15.0	6.0	79.6	1.0	-2.5	-2.5	22.5	22.5	-22.5	-22.5	-22.5	-22.5	6.5	6.5	1.0	1.0
9 7	2.5	4.0	6.0	79.5	1.0	0.2	0.2	11.5	11.5	-11.0	-11.0	-11.5	-11.5	-0.5	-0.5	2.0	2.0
9 8	5.5	-4.0	4.0	79.5	1.0	-4.0	-4.0	26.5	26.5	-27.0	-27.0	-27.5	-27.5	10.0	10.0	-0.5	-0.5
9 9	2.5	8.0	6.0	79.5	1.0	-1.0	-1.0	18.0	18.0	-17.5	-17.5	-18.0	-18.0	2.5	2.5	2.5	2.5
9 10	5.5	-15.0	6.0	79.5	1.0	-3.0	-3.0	24.0	23.5	-24.0	-24.0	-24.0	-24.0	7.5	7.5	0.5	0.5
9 11	5.5	15.0	4.0	79.5	1.0	-2.5	-2.5	23.0	23.0	-23.5	-23.5	-23.5	-23.5	7.0	7.0	1.0	1.0
9 12	2.5	-15.0	4.0	79.5	1.0	-3.2	-3.2	24.0	24.0	-24.0	-24.0	-24.0	-24.0	8.5	8.5	0.0	0.0
9 13	5.5	4.0	4.0	79.5	1.0	-0.8	-0.8	19.5	19.5	-19.5	-19.5	-20.5	-20.5	3.0	3.0	3.0	3.0
9 14	2.5	-15.0	6.0	79.5	1.0	-3.2	-3.2	24.0	24.0	-23.5	-23.5	-23.5	-23.5	8.5	8.5	0.0	0.0
9 15	2.5	8.0	4.0	79.4	1.0	-2.0	-2.0	21.0	21.0	-21.0	-21.0	-21.5	-21.5	6.0	6.0	1.5	1.5
9 16	5.5	-4.0	6.0	79.4	1.0	-5.0	-5.0	28.0	28.0	-28.5	-28.5	-29.0	-29.0	12.0	12.0	-1.5	-1.5
9 17	5.5	8.0	4.0	79.4	1.0	-1.7	-1.8	20.0	20.0	-20.0	-20.0	-20.5	-20.5	5.0	5.0	2.0	1.5
9 18	2.5	4.0	4.0	79.3	1.0	-0.2	-0.3	16.0	16.0	-16.0	-16.0	-16.5	-16.5	1.0	1.0	3.5	3.5
9 19	5.5	-15.0	4.0	79.3	1.0	-2.8	-2.8	23.5	23.5	-23.5	-23.5	-24.0	-24.0	7.5	7.5	0.5	0.5
9 20	5.5	4.0	6.0	79.3	1.0	-0.2	-0.2	17.5	17.5	-17.0	-17.0	-17.5	-17.5	1.0	1.0	3.5	3.5
STANDARD				79.3	1.0	-2.8	-2.8	23.5	23.5	-23.5	-23.5	-24.0	-24.0	7.5	7.5	0.5	0.5
ZERO						0.0		0.5		0.0		0.0		0.0		0.0	

SERIES 10

V SET	W INT	ALPHA	B DYN	B INT
1	4	105	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.8	1.0	2.8	2.8	22.5	22.5	-23.0	-23.0	-25.0	-25.0	-1.5	-1.5	11.0	11.0
10 1	5.5	-15.0	4.0	78.8	1.0	2.9	2.8	22.5	22.5	-23.0	-23.0	-25.0	-25.0	-1.5	-1.5	11.0	11.0
10 2	2.5	-15.0	6.0	78.8	1.0	2.4	2.4	22.5	22.5	-23.0	-23.0	-25.0	-25.0	-1.0	-1.0	10.0	10.0
10 3	5.5	-15.0	6.0	79.0	1.0	2.8	2.8	22.5	22.5	-23.0	-23.0	-25.0	-25.0	-1.5	-1.5	10.5	10.5
10 4	2.5	-4.0	4.0	79.0	1.0	0.0	0.0	25.0	25.0	-25.5	-25.5	-27.5	-27.5	3.5	3.5	6.0	6.0
10 5	2.5	8.0	6.0	78.8	1.0	3.4	3.9	12.5	12.5	-12.0	-12.0	-14.0	-13.5	-5.0	-5.0	10.0	10.0
10 6	5.5	4.0	6.0	79.0	1.0	6.0	6.0	18.5	18.5	-18.0	-18.0	-21.0	-21.0	-8.5	-8.5	14.0	14.0
10 7	5.5	-4.0	4.0	79.0	1.0	0.8	0.8	26.0	26.5	-27.0	-26.5	-29.5	-29.0	2.5	2.5	7.5	7.5
10 8	5.5	4.0	4.0	79.0	1.0	5.4	5.2	21.0	21.0	-21.0	-21.0	-23.5	-24.0	-6.5	-6.5	14.0	14.0
10 9	2.5	15.0	6.0	79.0	1.0	3.5	3.5	21.0	20.0	-21.0	-20.0	-23.5	-22.5	-2.5	-2.5	12.5	11.5
10 10	2.5	4.0	6.0	79.0	1.0	4.0	4.0	8.5	8.5	-8.5	-8.5	-10.0	-10.0	-6.0	-6.0	8.5	8.5
10 11	2.5	4.0	4.0	79.0	1.0	5.0	5.0	14.5	14.5	-14.0	-14.0	-16.5	-15.5	-6.0	-6.0	12.0	12.0
10 12	5.5	8.0	6.0	79.0	1.0	4.6	4.6	17.5	17.5	-17.5	-17.5	-20.0	-20.0	-5.5	-5.5	12.5	12.5
10 13	5.5	15.0	6.0	79.0	1.0	3.5	3.5	21.5	21.5	-21.5	-21.5	-24.0	-24.0	-2.5	-2.5	11.0	11.5
10 14	5.5	-4.0	6.0	79.0	1.0	-1.0	-1.0	29.0	29.0	-30.0	-29.0	-31.5	-31.5	6.0	5.0	5.0	5.0
10 15	2.5	8.0	4.0	79.0	1.0	4.0	4.0	17.5	17.5	-17.5	-17.5	-19.0	-19.0	-3.5	-3.5	11.5	11.5
10 16	2.5	-15.0	4.0	79.0	1.0	2.5	2.5	22.5	22.5	-22.5	-22.5	-24.5	-24.5	-1.0	-1.0	10.0	10.0
10 17	5.5	8.0	4.0	79.0	1.0	4.0	4.0	20.0	20.0	-20.0	-20.0	-22.0	-22.0	-3.5	-4.0	11.5	11.5
10 18	2.5	-4.0	6.0	79.0	1.0	-2.0	-1.4	26.5	26.5	-27.0	-27.0	-28.5	-28.0	7.5	7.5	3.5	3.5
10 19	2.5	15.0	4.0	79.0	1.0	3.2	3.0	22.0	22.0	-21.5	-21.5	-24.0	-24.0	-2.0	-2.0	11.0	11.0
10 20	5.5	15.0	4.0	79.0	1.0	3.0	3.0	22.0	22.0	-22.0	-22.0	-24.0	-24.0	-2.0	-2.0	10.5	10.5
STANDARD				79.0	1.0	2.8	2.8	22.5	22.5	-22.5	-22.5	-24.5	-24.5	-1.5	-1.5	10.0	10.0
ZERO						0.2		0.2		0.0		0.0		0.0		0.0	

SERIES 11

V SET	W INT	ALPHA	B DYN	B INT
3	2	105	75	105

TEST		X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO							0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD					78.8	3.0	-3.4	-3.4	25.0	25.0	-26.5	-26.5	-26.5	-26.5	9.0	9.0	0.0	0.0
11	1	5.5	15.0	6.0	78.7	3.0	-2.5	-2.5	24.0	24.0	-25.0	-25.0	-25.0	-25.0	7.5	7.5	1.0	1.0
11	2	5.5	8.0	4.0	78.7	3.0	-1.5	-1.5	22.0	22.0	-22.5	-22.5	-22.5	-22.5	5.0	5.0	2.5	2.5
11	3	5.5	-15.0	6.0	78.6	3.0	-3.2	-3.2	25.5	25.5	-26.5	-26.5	-26.5	-26.5	9.0	9.0	0.0	0.0
11	4	5.5	-4.0	4.0	78.7	3.0	-4.6	-4.7	29.0	29.0	-30.0	-30.0	-30.5	-30.5	12.0	12.0	-1.5	-1.5
11	5	5.5	4.0	4.0	78.7	3.0	-1.0	-1.0	23.0	23.0	-23.5	-23.5	-24.0	-24.0	4.0	4.0	3.0	2.5
11	6	2.5	4.0	6.0	78.7	3.0	0.3	0.2	11.5	11.5	-11.5	-11.5	-11.5	-11.5	0.0	0.0	2.5	2.0
11	7	2.5	-4.0	6.0	78.7	3.0	-5.6	-5.6	29.5	29.5	-30.5	-31.0	-31.5	-31.5	14.0	14.0	-2.5	-2.5
11	8	2.5	-15.0	6.0	78.7	3.0	-3.5	-3.5	24.5	24.5	-25.5	-25.5	-25.5	-25.5	9.5	9.5	-0.5	-0.5
11	9	2.5	15.0	4.0	78.7	3.0	-3.0	-3.0	24.0	24.0	-25.0	-25.0	-25.0	-25.0	8.5	8.5	0.5	0.5
11	10	5.5	8.0	6.0	78.7	3.0	-0.8	-0.7	20.0	20.0	-20.5	-20.5	-21.0	-21.0	3.5	3.5	2.5	2.5
11	11	2.5	-15.0	4.0	78.5	3.0	-3.6	-3.6	24.5	24.5	-26.0	-25.5	-25.5	-25.5	10.0	10.0	-0.5	-0.5
11	12	5.5	15.0	4.0	78.5	3.0	-2.8	-2.8	24.5	24.5	-26.0	-25.5	-26.0	-26.0	8.5	8.5	1.0	1.0
11	13	5.5	-4.0	6.0	78.5	3.0	-6.5	-6.5	31.5	31.5	-33.5	-32.5	-33.5	-33.0	15.0	15.0	-3.0	-3.0
11	14	5.5	4.0	6.0	78.5	3.0	-0.5	-0.5	21.0	21.0	-21.5	-21.5	-22.0	-22.0	2.5	2.5	3.5	3.5
11	15	2.5	-4.0	4.0	78.5	3.0	-4.5	-4.5	27.0	27.0	-28.5	-28.5	-28.5	-28.5	11.5	11.5	-1.0	-1.0
11	16	2.5	15.0	6.0	78.5	3.0	-2.8	-2.7	23.5	23.5	-24.5	-24.5	-24.5	-24.5	8.5	8.5	1.0	1.0
11	17	2.5	8.0	6.0	78.5	3.0	-0.5	-0.5	16.5	16.5	-17.5	-17.5	-17.5	-17.5	2.5	2.5	2.5	2.5
11	18	2.5	8.0	4.0	78.5	3.0	-1.6	-1.6	20.5	20.5	-21.0	-21.5	-21.0	-21.5	6.0	6.0	1.5	1.5
11	19	5.5	-15.0	4.0	78.5	3.0	-3.5	-3.5	25.5	25.5	-26.5	-26.5	-26.5	-26.5	9.5	9.5	-0.5	-0.5
11	20	2.5	4.0	4.0	78.5	3.0	0.0	0.0	16.0	16.0	-16.5	-16.5	-16.5	-16.5	2.0	2.0	3.5	3.5
STANDARD					78.5	3.0	-3.8	-3.8	24.0	24.0	-25.0	-25.0	-25.0	-25.0	10.0	10.0	-1.0	-1.0
ZERO							0.0		0.0		0.0		0.0		0.0		0.0	

SERIES 12

V SET	W INT	ALPHA	B DYN	B INT
1	4	75	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.5		0.0		0.0		0.0		0.0	
STANDARD				79.0	1.0	-2.6	-2.6	16.5	16.5	-18.5	-18.5	-15.0	-15.0	3.5	3.5	-3.0	-3.0
12 1	2.5	-15.0	6.0	78.8	1.0	-2.7	-2.8	16.5	16.5	-18.5	-18.5	-15.0	-15.0	3.5	3.5	-3.0	-3.0
12 2	5.5	-4.0	6.0	78.8	1.0	-5.2	-5.2	21.0	21.0	-25.5	-25.5	-18.5	-18.5	8.0	8.0	-6.5	-6.5
12 3	5.5	-15.0	6.0	78.8	1.0	-2.5	-2.5	16.5	16.5	-18.5	-18.5	-15.0	-15.0	3.0	3.0	-3.0	-3.0
12 4	5.5	-15.0	4.0	78.9	1.0	-2.5	-2.5	16.5	16.5	-18.5	-18.5	-15.0	-15.5	3.5	3.5	-3.0	-3.0
12 5	2.5	-4.0	6.0	79.3	1.0	-6.0	-6.0	20.0	20.0	-25.0	-25.0	-16.5	-16.5	10.0	10.0	-8.0	-8.0
12 6	5.5	4.0	4.0	79.5	1.0	-1.0	-1.0	13.0	13.0	-13.0	-13.0	-13.5	-13.5	-0.5	-0.5	0.0	0.0
12 7	5.5	8.0	6.0	79.3	1.0	-0.8	-0.9	11.5	11.5	-11.5	-11.5	-12.0	-12.0	0.0	0.0	0.0	0.0
12 8	2.5	8.0	4.0	79.2	1.0	-1.2	-1.4	11.5	11.5	-12.0	-12.0	-11.5	-11.5	1.0	1.0	-1.0	-1.0
12 9	5.5	4.0	6.0	79.2	1.0	-0.2	-0.2	11.5	11.5	-11.0	-11.0	-12.5	-12.5	-1.5	-1.5	1.0	1.0
12 10	2.5	-15.0	4.0	79.1	1.0	-2.7	-2.8	16.5	16.5	-18.5	-18.0	-15.5	-15.5	3.5	3.5	-3.0	-3.0
12 11	2.5	4.0	4.0	79.0	1.0	-0.2	-0.3	9.0	9.0	-8.5	-8.5	-10.0	-10.0	-1.0	-1.0	1.0	1.0
12 12	2.5	15.0	4.0	79.0	1.0	-2.3	-2.3	15.0	15.0	-16.5	-16.5	-14.0	-14.0	3.0	3.0	-2.0	-2.0
12 13	2.5	8.0	6.0	79.0	1.0	-0.4	-0.3	8.0	8.0	-7.5	-7.5	-8.5	-9.0	-1.0	-1.0	0.5	0.5
12 14	5.5	-4.0	4.0	79.0	1.0	-4.0	-4.0	19.5	19.5	-23.0	-23.0	-18.0	-18.0	5.5	5.5	-4.0	-4.0
12 15	5.5	15.0	6.0	79.0	1.0	-2.1	-2.2	14.5	14.5	-16.0	-16.0	-14.0	-14.0	2.5	2.5	-2.0	-2.0
12 16	5.5	15.0	4.0	79.0	1.0	-2.2	-2.2	15.0	15.0	-16.5	-16.5	-14.5	-14.5	2.5	2.5	-2.0	-2.0
12 17	2.5	-4.0	4.0	79.0	1.0	-4.5	-4.5	19.0	19.0	-22.5	-22.5	-16.5	-16.5	7.0	7.0	-5.5	-5.5
12 18	2.5	15.0	6.0	79.1	1.0	-2.0	-2.0	14.0	13.5	-14.5	-15.0	-13.0	-13.0	2.0	2.0	-1.5	-1.5
12 19	5.5	8.0	4.0	78.8	1.0	-1.6	-1.7	13.5	13.5	-14.0	-14.0	-13.5	-13.5	1.5	1.5	-1.0	-1.0
12 20	2.5	4.0	6.0	78.8	1.0	0.1	0.1	5.5	5.5	-4.5	-4.5	-6.0	-6.0	-2.0	-2.0	1.0	1.0
STANDARD				78.8	1.0	-2.7	-2.7	16.5	16.5	-18.5	-18.5	-15.5	-15.5	3.5	3.5	-3.0	-3.0
ZERO						0.0		0.0		0.0		-0.5		0.0		0.0	

SERIES 13

V SET	W INT	ALPHA	B DYN	B INT
3	4	75	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.1		0.5		0.5		0.0		0.2		0.0	
STANDARD				78.8	3.0	-2.8	-2.8	19.0	19.0	-21.5	-21.5	-17.5	-17.5	5.0	5.0	-4.0	-4.0
13 1	5.5	15.0	6.0	78.9	3.0	-1.3	-1.4	15.5	15.5	-16.5	-16.5	-15.0	-15.0	2.0	2.0	-1.5	-1.5
13 2	5.5	8.0	4.0	78.9	3.0	-1.2	-1.2	15.0	15.0	-16.0	-16.0	-14.5	-14.5	1.5	1.5	-1.0	-1.0
13 3	2.5	-15.0	6.0	78.8	3.0	-3.0	-3.0	18.5	18.5	-21.0	-21.0	-16.5	-16.5	5.0	5.0	-4.0	-4.0
13 4	5.5	-4.0	4.0	78.8	3.0	-4.8	-4.7	23.5	23.5	-28.0	-28.0	-20.5	-20.5	8.5	8.5	-6.5	-6.5
13 5	2.5	8.0	4.0	78.7	3.0	-1.0	-1.0	12.0	12.0	-13.0	-13.0	-12.0	-12.0	1.5	1.5	-1.0	-1.0
13 6	2.5	15.0	4.0	78.7	3.0	-1.8	-1.8	15.0	15.0	-16.5	-16.5	-13.5	-13.5	3.5	3.5	-2.5	-2.5
13 7	2.5	4.0	6.0	78.7	3.0	0.5	0.5	6.0	6.0	-5.0	-5.0	-6.0	-6.0	-1.5	-1.5	0.5	0.5
13 8	5.5	-15.0	4.0	78.6	3.0	-2.8	-2.8	19.0	19.0	-21.5	-21.5	-17.5	-17.5	5.0	5.0	-4.0	-4.0
13 9	2.5	4.0	4.0	78.7	3.0	0.0	0.0	9.5	9.5	-9.0	-9.5	-10.0	-10.0	-0.5	-0.5	0.0	0.0
13 10	2.5	8.0	6.0	78.8	3.0	0.1	0.1	8.0	8.0	-7.5	-7.5	-9.0	-9.0	-0.5	-0.5	0.5	0.5
13 11	2.5	-15.0	4.0	79.0	3.0	-3.0	-3.0	18.5	18.5	-21.5	-21.5	-17.0	-17.0	5.0	5.0	-4.5	-4.5
13 12	5.5	4.0	4.0	79.2	3.0	-0.5	-0.5	15.0	15.0	-15.5	-15.5	-15.5	-15.5	0.5	0.5	-0.5	-0.5
13 13	5.5	15.0	4.0	79.3	3.0	-2.0	-2.0	16.5	16.5	-18.5	-18.5	-16.0	-16.0	3.0	3.0	-2.5	-2.5
13 14	2.5	15.0	6.0	79.2	3.0	-1.4	-1.4	12.5	12.5	-14.0	-14.0	-12.0	-11.5	2.5	2.5	-2.0	-2.0
13 15	5.5	8.0	6.0	79.1	3.0	-0.2	-0.2	14.0	13.5	-13.5	-13.5	-14.0	-14.0	-0.5	-0.5	0.0	0.0
13 16	5.5	-4.0	6.0	79.1	3.0	-6.6	-6.7	26.0	26.0	-32.5	-32.5	-22.0	-22.0	11.5	11.5	-9.0	-9.0
13 17	2.5	-4.0	6.0	79.1	3.0	-6.7	-6.8	23.5	23.5	-30.0	-30.0	-19.0	-19.0	12.0	12.0	-9.0	-9.0
13 18	2.5	-4.0	4.0	79.1	3.0	-5.0	-5.0	22.0	22.0	-26.0	-26.5	-19.0	-19.0	8.5	8.5	-7.0	-7.0
13 19	5.5	4.0	6.0	79.0	3.0	0.2	0.3	14.0	14.0	-13.0	-13.0	-14.0	-14.0	-1.5	-1.5	0.0	0.0
13 20	5.5	-15.0	6.0	79.0	3.0	-2.8	-2.8	19.0	19.0	-21.5	-21.5	-17.5	-17.5	5.0	5.0	-4.0	-4.0
STANDARD				79.0	3.0	-2.8	-2.8	19.0	19.0	-22.0	-22.0	-17.5	-17.5	5.0	5.0	-4.0	-4.0
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	

SERIES 14

V SET	W INT	ALPHA	B DYN	B INT
3	2	105	105	105

TEST		X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO							-0.1		0.3		-0.3		0.0		0.0		0.0	
STANDARD					79.4	3.0	3.0	2.6	24.5	24.0	-24.5	-24.0	-26.5	-26.0	-2.0	-2.0	10.5	10.0
14	1	2.5	-4.0	4.0	79.5	3.0	1.8	1.4	26.5	26.0	-26.5	-26.0	-28.5	-28.0	0.0	0.0	9.0	9.0
14	2	2.5	8.0	4.0	79.2	3.0	3.0	3.2	22.0	22.0	-21.0	-21.5	-23.0	-23.0	-3.0	-3.0	12.0	11.0
14	3	5.5	15.0	4.0	79.3	3.0	3.5	3.2	25.5	25.0	-25.0	-27.5	-27.5	-27.5	-2.5	-2.5	11.5	11.0
14	4	5.5	4.0	6.0	79.3	3.0	5.0	5.5	21.5	22.0	-21.0	-20.5	-23.0	-23.0	-7.0	-7.5	13.0	13.0
14	5	2.5	15.0	6.0	79.2	3.0	3.3	3.3	23.0	23.5	-22.5	-22.5	-25.0	-24.5	-3.0	-3.0	11.5	12.0
14	6	2.5	-15.0	6.0	79.0	3.0	1.8	2.0	24.0	23.5	-23.0	-23.5	-25.0	-25.0	-2.0	-2.5	10.0	9.5
14	7	5.5	4.0	4.0	79.0	3.0	5.0	4.6	23.5	23.5	-23.0	-22.5	-25.0	-25.5	-6.5	-6.0	13.5	13.0
14	8	5.5	8.0	6.0	79.0	3.0	4.2	4.0	21.0	21.5	-20.0	-20.5	-22.0	-22.5	-6.0	-5.5	12.0	12.0
14	9	5.5	-15.0	4.0	79.0	3.0	3.0	2.5	25.0	25.0	-25.0	-25.0	-27.0	-27.0	-3.0	-2.5	11.5	11.0
14	10	2.5	15.0	4.0	79.0	3.0	3.3	3.0	24.0	23.5	-23.0	-23.0	-25.0	-25.0	-2.5	-2.5	11.0	10.5
14	11	5.5	-15.0	6.0	78.9	3.0	2.9	3.0	25.5	25.5	-25.0	-24.5	-26.5	-26.5	-3.0	-3.0	10.5	11.0
14	12	2.5	-4.0	6.0	79.0	3.0	1.0	0.8	28.0	28.0	-27.5	-27.5	-29.5	-30.0	-2.5	-2.5	6.5	7.0
14	13	2.5	4.0	6.0	78.9	3.0	5.3	5.2	13.0	13.0	-12.0	-12.5	-13.5	-13.5	-9.0	-9.0	10.5	11.0
14	14	2.5	4.0	4.0	78.9	3.1	5.0	5.4	17.5	18.0	-16.5	-16.5	-18.0	-18.5	-7.0	-7.0	12.5	12.0
14	15	2.5	-15.0	4.0	78.8	3.0	2.8	2.9	24.5	24.0	-23.5	-23.0	-25.5	-25.0	-2.5	-2.0	9.5	9.5
14	16	2.5	8.0	6.0	78.8	3.0	4.1	4.0	18.0	17.5	-16.5	-16.5	-18.0	-18.0	-5.5	-5.0	10.5	10.0
14	17	5.5	8.0	4.0	78.7	3.0	3.4	3.5	22.0	22.5	-22.0	-22.5	-23.0	-23.5	-4.0	-4.0	11.0	11.0
14	18	5.5	-4.0	4.0	78.6	3.0	1.8	2.1	28.0	27.5	-27.0	-26.0	-29.0	-28.5	-1.0	-1.0	9.5	9.0
14	19	5.5	-4.0	6.0	78.6	3.0	0.2	0.8	30.0	30.0	-29.5	-29.0	-31.0	-31.5	2.0	1.5	7.5	7.5
14	20	5.5	15.0	6.0	78.6	3.1	3.7	3.1	24.5	24.5	-23.5	-23.5	-25.5	-25.5	-3.5	-3.5	11.0	10.5
STANDARD					78.7	3.1	3.0	3.5	25.0	25.0	-24.5	-24.0	-26.0	-26.0	-2.5	-2.5	10.0	10.5
ZERO							0.3		1.0		0.0		1.0		-0.5		-0.5	

SERIES 15

V SET	W INT	ALPHA	B DYN	B INT
3	2	75	105	75

TEST		X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO							-0.3		0.0		0.0		0.0		-0.5		-1.0	
STANDARD					78.5	2.9	2.0	2.0	17.5	17.5	-15.0	-14.5	-22.0	-21.5	-5.0	-5.0	5.0	5.0
15	1	2.5	4.0	6.0	78.3	2.9	3.8	3.5	11.0	11.0	-7.0	-7.0	-16.0	-16.5	-8.0	-8.0	6.5	6.5
15	2	5.5	8.0	4.0	78.3	3.0	2.5	2.0	16.0	16.0	-13.0	-13.0	-21.0	-20.5	-6.0	-6.0	5.5	5.5
15	3	5.5	4.0	6.0	78.3	3.0	3.2	3.5	16.5	16.5	-12.0	-12.5	-21.5	-22.0	-7.5	-8.0	7.5	7.5
15	4	5.5	15.0	6.0	78.3	2.9	2.2	2.3	16.5	16.5	-14.0	-13.5	-20.5	-20.5	-6.0	-6.0	5.0	5.0
15	5	5.5	4.0	4.0	78.3	2.9	3.0	3.3	17.0	17.0	-13.0	-13.0	-21.5	-22.0	-7.0	-7.0	6.5	6.5
15	6	2.5	-4.0	6.0	78.1	2.9	1.5	1.3	20.0	19.5	-17.5	-17.5	-23.0	-23.0	-3.5	-3.0	3.5	3.5
15	7	2.5	15.0	6.0	78.0	2.9	2.7	2.4	15.5	15.5	-13.0	-12.5	-20.0	-19.5	-5.5	-5.5	5.0	5.0
15	8	2.5	15.0	4.0	78.1	2.9	2.6	2.4	16.0	16.5	-13.5	-13.5	-20.5	-20.0	-5.5	-5.5	5.0	4.5
15	9	5.5	15.0	4.0	78.1	2.9	2.0	2.6	17.0	17.0	-14.0	-14.0	-21.5	-21.5	-5.5	-5.5	5.0	5.0
15	10	5.5	8.0	6.0	78.2	2.8	2.9	3.0	15.5	15.5	-12.0	-12.0	-20.0	-19.5	-6.0	-6.0	6.0	6.0
15	11	2.5	8.0	4.0	78.1	2.9	2.2	2.8	15.0	15.0	-12.0	-12.0	-19.0	-19.0	-6.0	-6.0	5.5	5.5
15	12	2.5	8.0	6.0	78.2	2.9	3.0	3.1	13.5	13.5	-9.5	-9.5	-18.5	-17.5	-7.0	-7.0	6.5	6.5
15	13	2.5	-4.0	4.0	78.0	2.9	1.8	2.0	19.0	19.0	-16.0	-16.5	-22.5	-23.0	-5.0	-4.5	4.5	4.5
15	14	5.5	-4.0	6.0	78.1	2.8	1.7	1.5	20.0	20.5	-18.0	-18.0	-24.0	-24.0	-4.5	-4.5	4.0	4.0
15	15	2.5	-15.0	4.0	78.2	2.8	2.0	2.0	17.5	17.5	-12.0	-12.0	-21.0	-21.5	-5.5	-5.5	4.5	5.0
15	16	2.5	-15.0	6.0	78.1	2.9	2.2	2.6	17.5	17.5	-14.5	-15.0	-21.5	-21.5	-5.0	-5.5	5.0	4.5
15	17	5.5	-15.0	4.0	78.0	2.8	2.6	2.3	18.0	18.0	-15.0	-15.0	-22.0	-22.5	-5.5	-5.5	5.0	5.5
15	18	5.5	-4.0	4.0	78.0	2.8	2.0	2.2	19.5	19.5	-16.5	-16.5	-23.5	-23.0	-5.0	-5.0	5.0	4.5
15	19	5.5	-15.0	6.0	78.0	2.8	2.1	2.5	18.0	17.5	-15.0	-15.0	-22.0	-22.0	-5.5	-5.5	5.0	5.0
15	20	2.5	4.0	4.0	78.0	2.8	3.3	3.5	13.0	13.0	-9.0	-9.5	-18.0	-18.0	-7.5	-7.5	7.0	7.0
STANDARD					78.0	2.8	2.7	2.2	17.5	17.5	-15.0	-14.5	-21.5	-21.5	-5.5	-5.0	5.0	4.5
ZERO							0.0		0.5		0.0		-0.5		-0.5		-0.5	

SERIES 16

V SET	W INT	ALPHA	B DYN	B INT
1	2	75	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.2		0.0		0.5		0.0		-0.5		-0.5	
STANDARD				78.3	1.0	2.4	2.3	16.0	16.0	-13.0	-13.0	-20.0	-19.5	-5.5	-5.5	5.0	5.0
16 1	5.5	4.0	6.0	78.3	1.0	3.7	3.6	15.0	14.5	-10.5	-10.0	-19.5	-19.0	-7.5	-7.5	7.0	6.5
16 2	2.5	8.0	4.0	78.3	0.9	2.8	2.9	14.0	14.5	-11.0	-11.0	-18.0	-18.0	-5.5	-5.5	4.5	5.0
16 3	5.5	-15.0	4.0	78.4	0.9	2.8	3.0	16.0	16.0	-12.5	-13.0	-19.0	-19.5	-5.5	-5.5	4.5	5.0
16 4	5.5	15.0	6.0	78.6	1.0	2.4	2.6	16.0	16.0	-12.5	-12.5	-19.0	-19.0	-5.5	-5.5	4.5	4.5
16 5	2.5	15.0	4.0	78.6	1.0	2.5	2.2	16.0	16.0	-13.0	-12.5	-19.0	-19.0	-5.0	-5.0	4.0	4.5
16 6	5.5	-4.0	4.0	78.5	1.0	2.2	2.2	17.0	17.5	-14.5	-14.5	-21.0	-21.0	-5.0	-5.0	4.0	4.0
16 7	5.5	-15.0	6.0	78.5	1.0	2.3	2.5	16.0	16.0	-13.0	-12.5	-19.5	-19.5	-6.0	-5.5	5.0	4.5
16 8	2.5	-15.0	4.0	78.5	1.0	2.2	2.7	16.0	16.0	-12.5	-12.5	-19.0	-19.0	-5.5	-5.5	4.5	4.5
16 9	5.5	8.0	4.0	78.6	1.0	3.0	2.4	15.0	14.5	-11.5	-11.5	-18.5	-18.0	-6.0	-5.5	4.5	4.5
16 10	2.5	15.0	6.0	78.7	1.0	2.7	2.5	15.5	15.5	-12.5	-12.5	-19.0	-19.0	-5.0	-5.0	4.5	4.5
16 11	5.5	15.0	4.0	78.6	0.9	2.3	2.5	15.5	16.0	-12.5	-12.5	-19.0	-19.5	-5.5	-5.5	5.0	5.0
16 12	5.5	-4.0	6.0	78.7	1.0	1.5	2.0	18.0	18.0	-16.0	-16.0	-21.0	-21.5	-3.5	-4.0	3.5	3.5
16 13	2.5	8.0	6.0	78.6	1.0	3.0	2.6	13.0	13.0	-9.0	-9.0	-17.5	-17.0	-7.0	-6.5	6.5	6.0
16 14	5.5	4.0	4.0	78.7	1.0	3.2	3.1	14.5	14.5	-11.0	-11.0	-19.0	-19.0	-6.5	-6.5	6.0	6.0
16 15	5.5	8.0	6.0	78.7	1.0	3.0	2.9	14.0	14.0	-11.0	-11.0	-18.0	-17.5	-6.0	-6.0	5.5	5.0
16 16	2.5	4.0	6.0	78.7	1.0	4.0	4.3	10.0	10.0	-5.5	-5.5	-14.5	-14.5	-8.5	-8.5	7.0	7.0
16 17	2.5	-4.0	6.0	78.6	1.0	1.2	1.2	17.5	17.0	-16.0	-16.0	-20.0	-20.0	-2.5	-2.5	2.5	2.5
16 18	2.5	-4.0	4.0	78.6	1.0	1.9	1.8	16.5	16.5	-14.5	-14.5	-20.0	-20.0	-4.0	-4.0	4.0	3.5
16 19	2.5	4.0	4.0	78.6	1.0	3.7	3.7	11.5	12.0	-8.0	-8.0	-16.5	-16.5	-7.0	-7.0	7.0	7.0
16 20	2.5	-15.0	6.0	78.6	0.9	2.5	2.4	15.5	15.5	-13.0	-13.0	-19.5	-19.5	-5.0	-5.0	4.5	4.5
STANDARD				78.6	1.0	2.4	2.6	15.0	15.5	-13.0	-13.0	-19.0	-19.5	-5.0	-5.0	4.5	4.5
ZERO						0.2		0.0		0.0		-0.5		-0.5		0.0	

SERIES 17

V SET	W INT	ALPHA	B DYN	B INT
3	4	75	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						-0.1		0.0		0.5		-0.5		-0.5		0.0	
STANDARD				78.0	3.0	2.3	2.4	18.0	18.0	-15.0	-14.5	-22.5	-22.5	-5.5	-5.5	6.0	6.0
17 1	5.5	-4.0	4.0	78.1	3.0	1.4	1.4	21.0	21.0	-19.0	-18.5	-25.5	-25.0	-4.5	-4.0	4.5	4.5
17 2	5.5	8.0	6.0	78.1	3.0	4.1	4.0	15.5	15.5	-10.0	-10.0	-21.5	-21.5	-9.0	-9.5	9.5	9.5
17 3	2.5	-15.0	6.0	78.1	3.0	2.0	2.2	17.5	17.5	-14.0	-14.5	-21.5	-21.5	-5.5	-5.5	5.5	5.5
17 4	2.5	8.0	6.0	78.1	3.0	3.3	3.3	9.0	9.0	-5.0	-5.0	-13.5	-13.5	-7.0	-7.0	6.5	7.0
17 5	5.5	4.0	4.0	78.2	3.0	4.5	4.3	17.5	17.5	-12.5	-12.5	-24.0	-23.5	-9.0	-9.0	9.0	9.0
17 6	2.5	4.0	6.0	78.1	3.0	3.0	3.3	7.0	7.5	-3.5	-3.5	-10.5	-10.5	-7.0	-7.0	5.0	5.0
17 7	2.5	15.0	6.0	78.1	3.0	2.2	2.4	13.0	13.0	-9.5	-9.5	-16.5	-17.0	-6.0	-6.0	6.0	6.0
17 8	5.5	4.0	6.0	78.1	3.0	4.7	4.7	16.5	16.5	-11.0	-11.0	-23.0	-23.5	-10.5	-10.5	9.5	9.5
17 9	5.5	15.0	4.0	78.0	3.0	2.6	2.8	17.8	17.5	-13.5	-13.5	-22.0	-22.0	-6.5	-6.5	6.5	6.5
17 10	5.5	-15.0	4.0	78.0	3.0	2.2	2.4	18.0	18.0	-14.5	-14.5	-22.0	-22.0	-6.0	-6.0	5.5	5.5
17 11	2.5	-15.0	4.0	78.0	3.0	2.3	2.1	17.0	17.5	-14.0	-14.0	-21.0	-21.0	-5.5	-5.5	5.0	5.0
17 12	2.5	-4.0	6.0	77.9	3.0	-0.4	-0.5	21.0	21.0	-20.5	-20.5	-23.0	-22.5	-0.5	0.0	1.5	1.0
17 13	5.5	-4.0	6.0	78.0	3.0	0.3	0.2	23.0	23.0	-21.5	-21.5	-26.0	-26.0	-2.5	-2.5	2.5	2.5
17 14	2.5	-4.0	4.0	78.1	3.0	0.2	0.8	20.0	20.0	-18.0	-18.0	-22.5	-22.5	-3.0	-3.0	3.0	3.0
17 15	2.5	4.0	4.0	78.1	3.0	3.6	3.1	10.0	10.5	-6.5	-6.0	-15.0	-14.5	-7.5	-7.5	7.0	7.0
17 16	5.5	-15.0	6.0	78.1	3.0	2.6	2.2	18.0	18.0	-14.5	-15.0	-22.0	-22.0	-6.0	-5.5	5.5	5.5
17 17	5.5	8.0	4.0	78.2	3.0	3.3	3.3	16.5	16.5	-12.0	-12.0	-21.0	-21.5	-7.5	-7.5	7.0	7.5
17 18	2.5	15.0	4.0	78.0	3.0	2.8	2.8	15.0	15.0	-11.0	-11.0	-19.5	-19.5	-6.0	-6.5	6.5	6.5
17 19	5.5	15.0	6.0	77.9	3.0	3.0	3.2	16.5	16.5	-12.5	-12.5	-21.5	-21.5	-7.0	-7.0	7.0	7.0
17 20	2.5	8.0	4.0	78.0	3.0	3.0	3.0	13.0	13.0	-9.0	-9.0	-17.0	-17.0	-6.5	-6.5	6.5	6.5
STANDARD				78.0	3.0	2.0	2.3	17.0	17.0	-14.0	-14.0	-21.0	-21.0	-5.0	-5.5	5.0	5.0
ZERO						0.0		0.0		0.5		-0.5		-0.5		0.0	

SERIES 18

V SET	W INT	ALPHA	B DYN	B INT
3	4	105	105	105

TEST		X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO							0.0		0.0		-0.5		0.5		-0.5		0.0	
STANDARD					78.6	3.0	2.3	2.2	24.0	24.0	-25.0	-25.0	-26.5	-26.5	-3.5	-3.5	11.5	11.5
18	1	5.5	8.0	4.0	78.6	3.0	4.2	4.3	21.0	21.0	-21.0	-21.5	-23.0	-23.0	-7.0	-7.0	14.0	14.0
18	2	5.5	4.0	6.0	78.5	3.0	5.7	5.8	20.0	20.5	-20.5	-21.0	-22.0	-22.5	-10.5	-10.5	13.5	13.5
18	3	2.5	4.0	6.0	78.5	3.0	3.2	3.3	8.5	8.0	-8.5	-8.5	-8.5	-9.0	-7.5	-7.5	8.5	8.5
18	4	2.5	4.0	4.0	78.4	3.0	4.2	4.2	14.0	14.0	-14.0	-14.5	-15.0	-15.0	-7.5	-7.5	12.0	12.0
18	5	2.5	8.0	6.0	78.5	3.0	4.0	3.7	11.5	11.5	-12.0	-12.0	-12.5	-12.5	-7.0	-7.5	10.5	10.5
18	6	2.5	15.0	6.0	78.5	3.0	3.3	3.2	18.0	18.0	-18.5	-18.5	-19.5	-19.5	-5.0	-5.0	12.0	12.0
18	7	2.5	-15.0	6.0	78.4	3.0	2.9	2.8	22.5	23.0	-23.5	-23.5	-24.5	-25.0	-2.5	-2.5	10.0	10.0
18	8	2.5	8.0	4.0	78.3	3.0	3.6	3.8	17.0	17.0	-17.0	-17.0	-18.0	-18.5	-6.5	-6.0	12.5	12.5
18	9	5.5	-15.0	6.0	78.3	3.0	2.6	2.3	23.0	23.5	-24.5	-24.0	-26.0	-26.0	-3.0	-3.0	11.0	11.5
18	10	5.5	8.0	6.0	78.3	3.0	4.6	5.0	18.0	18.0	-18.5	-18.5	-20.5	-20.0	-9.0	-9.0	14.0	14.5
18	11	2.5	-4.0	6.0	78.2	3.0	-2.2	-2.2	28.0	28.5	-29.5	-29.5	-31.0	-31.0	6.0	7.0	4.5	4.0
18	12	2.5	-4.0	4.0	78.2	3.0	-0.3	0.0	26.0	26.0	-27.5	-27.0	-28.0	-28.5	2.0	2.0	7.0	7.0
18	13	5.5	-4.0	4.0	78.2	3.0	0.2	-0.2	28.5	28.0	-30.0	-29.5	-31.5	-31.0	1.5	1.5	8.5	8.0
18	14	2.5	-15.0	4.0	78.3	3.0	2.0	2.2	22.0	22.5	-23.5	-23.5	-24.5	-24.5	-2.5	-3.0	10.5	10.5
18	15	5.5	15.0	6.0	78.2	3.0	4.0	3.8	21.0	21.5	-22.0	-22.5	-23.5	-23.5	-6.0	-6.0	14.0	14.5
18	16	5.5	15.0	4.0	78.2	3.0	3.3	3.3	22.5	22.0	-23.0	-23.0	-24.5	-24.5	-5.0	-5.0	13.0	13.0
18	17	5.5	-15.0	4.0	78.3	3.0	2.6	2.0	23.0	23.0	-24.0	-23.5	-25.5	-25.0	-3.0	-3.0	11.0	11.0
18	18	2.5	15.0	4.0	78.1	3.0	3.2	2.8	20.0	20.5	-21.0	-21.0	-22.0	-22.5	-4.5	-4.5	12.5	12.5
18	19	5.5	-4.0	6.0	78.3	3.0	-2.3	-2.8	32.0	31.0	-34.0	-33.0	-35.0	-33.5	7.0	7.0	4.5	4.0
18	20	5.5	4.0	4.0	78.3	3.0	4.4	4.7	22.0	22.0	-23.0	-22.5	-24.5	-24.5	-8.5	-8.5	15.0	15.5
STANDARD					78.3	3.0	2.2	2.4	22.5	23.0	-23.0	-24.0	-24.5	-25.0	-3.5	-3.5	10.5	11.0
ZERO							0.0		0.0		-0.5		0.0		-0.5		0.0	

SERIES 19

V SET	W INT	ALPHA	B DYN	B INT
1	2	105	105	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		-0.5		-0.5	
STANDARD				79.7	0.9	2.3	2.8	23.0	22.5	-23.0	-23.0	-25.0	-24.5	-1.0	-1.5	9.5	9.5
19 1	2.5	-15.0	4.0	79.7	0.9	2.2	2.1	22.5	22.5	-23.0	-23.0	-25.0	-25.0	-1.0	-1.0	9.5	9.0
19 2	5.5	15.0	6.0	79.6	0.9	2.8	2.6	22.0	22.5	-22.5	-22.5	-24.5	-24.5	-2.0	-2.0	10.0	10.0
19 3	5.5	-4.0	6.0	79.6	0.9	1.0	0.8	26.0	26.0	-27.0	-27.0	-29.0	-29.0	2.5	2.0	7.5	7.0
19 4	2.5	4.0	4.0	79.5	0.9	5.0	5.2	16.5	17.0	-16.5	-17.0	-18.5	-19.5	-6.5	-6.5	12.5	13.0
19 5	5.5	4.0	6.0	79.5	0.9	5.0	4.7	19.0	18.5	-19.0	-18.5	-21.5	-21.0	-6.5	-6.5	12.5	12.5
19 6	2.5	-4.0	4.0	79.5	1.0	1.2	1.2	24.0	24.0	-24.0	-24.5	-26.5	-26.5	1.0	1.0	8.0	7.5
19 7	2.5	-15.0	6.0	79.4	1.0	2.6	2.1	23.0	22.0	-23.0	-22.5	-25.0	-24.0	-1.0	-1.0	9.5	9.0
19 8	5.5	4.0	4.0	79.4	0.9	4.3	4.3	21.0	21.0	-21.0	-20.5	-23.5	-23.0	-5.0	-5.0	12.0	12.0
19 9	5.5	-4.0	4.0	79.4	0.9	1.3	1.8	24.0	25.0	-24.5	-25.0	-26.5	-27.0	0.0	0.0	8.5	8.5
19 10	2.5	4.0	6.0	79.3	0.9	5.2	4.8	12.0	12.0	-12.0	-11.5	-13.0	-13.0	-8.0	-7.5	10.5	10.0
19 11	5.5	8.0	6.0	79.2	0.9	3.7	3.5	18.5	18.5	-18.5	-18.5	-20.5	-20.5	-3.5	-3.5	10.0	10.0
19 12	5.5	15.0	4.0	79.3	0.9	2.5	2.7	22.0	22.0	-22.5	-22.5	-24.0	-24.5	-2.0	-2.0	10.0	9.5
19 13	5.5	-15.0	4.0	79.3	1.0	2.2	2.6	22.0	22.0	-22.5	-22.5	-24.5	-24.5	-2.0	-2.0	9.5	9.5
19 14	5.5	-15.0	6.0	79.2	0.9	2.8	2.5	22.5	22.0	-22.5	-22.5	-24.5	-24.5	-2.0	-2.0	9.5	9.5
19 15	5.5	8.0	4.0	79.3	0.9	2.8	3.3	20.5	20.5	-20.5	-20.5	-22.5	-22.0	-3.0	-3.0	10.0	10.0
19 16	2.5	8.0	6.0	79.4	0.9	3.3	3.6	17.0	17.5	-17.0	-17.5	-18.5	-19.0	-4.0	-4.0	9.5	10.0
19 17	2.5	-4.0	6.0	79.3	0.9	-0.2	-0.3	24.5	24.5	-25.5	-25.5	-27.5	-27.0	3.5	3.5	5.5	5.5
19 18	2.5	15.0	6.0	79.2	0.9	2.3	2.2	22.0	22.0	-22.5	-22.0	-24.5	-24.0	-1.5	-1.5	10.0	9.5
19 19	2.5	8.0	4.0	79.2	0.9	2.8	3.1	20.0	19.5	-20.0	-19.5	-22.0	-21.5	-2.5	-2.5	9.5	9.5
19 20	2.5	15.0	4.0	79.3	0.9	2.1	2.1	22.5	22.0	-22.5	-22.5	-24.0	-24.0	-1.0	-1.0	9.0	9.0
STANDARD				79.3	0.9	2.0	2.2	22.0	22.0	-22.5	-22.0	-24.0	-24.0	-1.0	-1.0	9.0	9.0
ZERO						0.0		0.0		0.0		0.0		-0.5		-0.5	

SERIES 20

V SET	W INT	ALPHA	B DYN	B INT
1	4	75	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.5		0.0		-0.5		-0.5	
STANDARD				79.6	1.0	-2.9	-2.3	16.0	16.0	-18.0	-18.0	-14.5	-14.5	3.0	3.0	-3.5	-3.0
20 1	5.5	4.0	4.0	79.5	1.0	-0.7	-0.5	13.5	13.5	-13.5	-13.5	-13.5	-13.5	-0.5	-1.0	-0.5	0.0
20 2	5.5	-15.0	4.0	79.3	1.0	-2.5	-2.7	16.0	16.0	-18.5	-18.5	-14.5	-14.5	3.0	3.0	-3.0	-3.0
20 3	5.5	15.0	6.0	79.2	0.9	-2.6	-2.4	15.5	15.5	-17.0	-17.0	-14.5	-14.0	2.0	2.0	-2.5	-2.5
20 4	2.5	8.0	6.0	79.4	0.9	-0.2	-0.4	8.5	8.5	-8.0	-8.0	-8.5	-8.5	-1.0	-1.0	0.0	0.0
20 5	2.5	4.0	4.0	79.5	0.9	-0.3	-0.3	8.5	8.5	-8.0	-8.0	-8.5	-8.5	-1.5	-1.5	0.5	0.5
20 6	5.5	4.0	6.0	78.9	0.9	-0.1	-0.3	12.5	12.5	-12.0	-12.0	-13.5	-13.5	-2.5	-2.0	0.5	0.5
20 7	5.5	-4.0	6.0	79.3	0.9	-6.0	-6.0	21.5	21.0	-27.0	-27.0	-18.0	-18.0	9.0	9.0	-8.0	-8.0
20 8	2.5	15.0	4.0	79.5	0.9	-1.9	-2.1	15.5	15.5	-17.5	-17.0	-14.5	-14.0	2.5	2.5	-2.5	-2.5
20 9	5.5	-4.0	4.0	79.6	1.0	-4.4	-4.2	19.5	19.5	-24.0	-23.5	-17.5	-17.5	6.0	6.0	-6.0	-5.5
20 10	5.5	15.0	4.0	79.5	0.9	-2.5	-2.7	16.0	16.0	-18.0	-18.0	-15.0	-15.0	2.5	2.5	-2.5	-2.5
20 11	5.5	8.0	4.0	79.5	0.9	-1.6	-1.8	14.0	14.0	-16.0	-15.5	-13.5	-13.5	1.0	1.0	-1.5	-1.5
20 12	5.5	8.0	6.0	79.5	0.9	-1.2	-0.8	12.5	12.5	-12.5	-12.5	-12.5	-12.5	-0.5	-0.5	0.0	0.0
20 13	2.5	8.0	4.0	79.4	0.9	-1.4	-1.4	12.0	12.0	-13.0	-13.0	-11.5	-11.5	1.0	1.0	-1.5	-1.0
20 14	2.5	-4.0	4.0	79.2	0.9	-4.7	-4.4	18.5	18.5	-23.0	-22.5	-16.0	-16.0	6.5	6.0	-6.0	-6.0
20 15	2.5	-15.0	4.0	79.2	0.9	-2.8	-2.8	16.0	16.0	-18.5	-18.5	-15.0	-15.0	3.5	3.5	-3.5	-3.5
20 16	2.5	-15.0	6.0	79.1	0.9	-2.6	-3.0	16.0	16.0	-18.5	-18.5	-14.5	-14.5	3.5	3.5	-3.5	-3.5
20 17	2.5	4.0	6.0	79.2	0.9	-0.1	0.1	5.0	5.0	-4.5	-4.5	-5.5	-5.5	-2.5	-2.5	0.5	0.5
20 18	2.5	-4.0	6.0	79.2	0.9	-6.0	-6.0	19.5	19.0	-25.0	-24.5	-16.0	-16.0	9.0	8.5	-7.5	-7.5
20 19	5.5	-15.0	6.0	79.3	0.9	-2.7	-2.9	16.0	16.0	-19.0	-18.5	-15.0	-15.0	3.0	3.0	-3.0	-3.0
20 20	2.5	15.0	6.0	79.2	0.9	-2.0	-2.2	13.5	14.0	-15.0	-15.5	-13.0	-13.0	2.0	2.0	-1.5	-2.0
STANDARD				79.2	0.9	-3.0	-2.7	16.0	16.0	-18.5	-18.5	-14.5	-14.5	3.5	3.5	-3.5	-3.5
ZERO						0.0		0.0		0.0		0.0		-0.5		0.0	

SERIES 21

V SET	W INT	ALPHA	B DYN	B INT
1	2	75	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.5		0.0		-0.5		0.0	
STANDARD				79.0	1.0	-2.4	-2.8	16.0	16.0	-18.0	-18.0	-14.5	-14.5	3.0	3.0	-3.0	-3.0
21 1	5.5	-4.0	4.0	79.0	1.0	-3.2	-3.6	17.5	17.5	-20.0	-20.0	-16.0	-15.5	4.0	4.0	-4.0	-4.0
21 2	2.5	8.0	6.0	78.9	1.0	-1.1	-1.2	12.0	12.5	-12.5	-12.5	-12.0	-12.0	0.5	0.0	-1.0	-1.0
21 3	5.5	8.0	6.0	78.8	1.0	-1.4	-1.7	13.0	13.0	-14.0	-14.0	-12.0	-12.0	1.0	1.0	-2.0	-2.0
21 4	2.5	4.0	6.0	79.0	1.0	0.2	0.2	9.0	9.0	-8.0	-7.5	-9.5	-9.0	-2.5	-2.5	0.5	0.5
21 5	5.5	15.0	4.0	79.0	1.0	-2.2	-2.2	15.5	15.0	-17.0	-17.0	-13.5	-13.5	2.5	2.5	-3.0	-3.0
21 6	5.5	-15.0	6.0	78.9	1.0	-2.7	-2.2	16.0	16.0	-17.5	-17.5	-14.0	-14.0	2.5	2.5	-3.0	-3.0
21 7	5.5	4.0	4.0	78.9	1.0	-1.2	-1.4	13.5	13.5	-13.5	-13.5	-12.5	-12.5	0.5	0.5	-1.5	-1.5
21 8	2.5	15.0	4.0	79.0	1.0	-2.5	-2.5	16.0	15.5	-17.0	-17.0	-13.5	-13.5	3.0	3.0	-4.0	-3.5
21 9	5.5	4.0	6.0	78.9	1.0	-1.0	-0.6	12.5	12.5	-12.5	-12.5	-12.5	-12.5	-1.0	-1.0	-0.5	-0.5
21 10	2.5	-4.0	4.0	78.7	1.0	-3.2	-3.2	17.5	17.5	-20.0	-19.5	-15.0	-15.0	4.5	4.5	-5.0	-5.0
21 11	2.5	15.0	6.0	79.1	1.0	-2.3	-2.3	16.0	16.0	-17.0	-17.0	-13.5	-13.5	3.0	3.0	-3.5	-3.5
21 12	2.5	8.0	4.0	79.3	1.0	-1.8	-2.3	14.5	14.5	-15.5	-16.0	-13.0	-13.0	2.0	2.0	-3.0	-3.0
21 13	2.5	-15.0	4.0	79.3	1.0	-2.2	-2.2	16.5	16.5	-18.0	-18.0	-14.5	-14.0	3.0	3.0	-3.5	-3.5
21 14	5.5	8.0	4.0	79.3	1.0	-2.0	-1.8	14.5	14.0	-15.0	-15.0	-13.0	-13.0	1.5	1.5	-2.5	-2.5
21 15	2.5	4.0	4.0	79.3	1.0	-0.3	-0.5	11.5	11.5	-11.0	-11.0	-11.5	-11.5	-1.0	-1.0	-0.5	-0.5
21 16	2.5	-4.0	6.0	79.0	1.0	-4.2	-4.6	18.5	19.0	-19.5	-20.0	-16.0	-16.0	6.5	6.5	-6.0	-6.5
21 17	5.5	-4.0	6.0	79.0	1.0	-4.2	-3.8	19.0	19.0	-22.0	-22.0	-16.0	-16.0	5.0	5.0	-5.5	-5.5
21 18	5.5	15.0	6.0	78.9	1.0	-2.0	-2.2	15.5	15.5	-16.5	-16.5	-13.5	-13.5	2.5	2.5	-3.0	-3.0
21 19	2.5	-15.0	6.0	78.9	1.0	-2.4	-2.6	16.0	16.5	-18.0	-18.0	-14.0	-14.5	3.0	3.0	-3.5	-3.5
21 20	5.5	-15.0	4.0	79.0	1.0	-2.2	-2.2	16.5	16.0	-18.0	-17.5	-14.0	-14.5	2.5	2.5	-3.5	-3.5
STANDARD				79.0	1.0	-2.4	-2.5	16.5	16.0	-17.5	-17.5	-14.5	-14.5	2.5	2.5	-3.5	-3.5
ZERO						0.2		0.0		0.5		0.0		-0.5		-0.5	

SERIES 22

V SET	W INT	ALPHA	B DYN	B INT
1	4	105	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.5		0.0		0.0		0.0		-0.5	
STANDARD				78.6	1.0	2.5	2.8	22.5	22.5	-22.0	-22.0	-24.0	-24.5	-2.0	-2.0	9.5	9.5
22 1	5.5	-4.0	6.0	78.6	1.0	-0.6	-1.0	28.5	28.0	-28.5	-28.5	-31.0	-30.5	4.0	4.5	6.0	5.5
22 2	5.5	15.0	4.0	78.6	1.0	3.0	2.8	21.5	21.0	-21.5	-21.0	-24.0	-23.0	-2.5	-2.5	10.0	10.0
22 3	2.5	15.0	6.0	78.7	1.0	2.6	2.8	20.5	20.0	-20.0	-19.5	-22.0	-21.5	-2.0	-2.0	9.5	9.5
22 4	5.5	-4.0	4.0	78.6	1.0	0.9	1.0	26.0	26.0	-26.5	-26.5	-29.0	-29.0	1.0	1.0	8.0	8.0
22 5	2.5	-15.0	6.0	78.6	1.0	1.8	2.2	22.5	23.0	-22.5	-22.5	-24.5	-24.5	-1.0	-1.0	9.0	9.0
22 6	2.5	4.0	6.0	78.7	1.0	3.2	3.0	8.0	8.0	-7.5	-7.5	-8.5	-8.5	-6.0	-5.5	6.5	6.0
22 7	2.5	-4.0	4.0	78.7	1.0	0.2	0.2	26.0	25.5	-25.5	-25.5	-27.5	-27.5	2.5	2.5	6.0	5.5
22 8	2.5	8.0	6.0	78.8	1.0	3.2	3.8	12.0	13.0	-11.5	-12.0	-13.0	-14.0	-4.5	-5.5	7.5	9.0
22 9	5.5	4.0	6.0	78.7	1.0	5.2	5.0	16.5	16.5	-16.0	-15.5	-18.0	-18.0	-7.5	-8.0	11.5	12.0
22 10	2.5	15.0	4.0	78.7	1.0	2.8	2.4	21.5	21.5	-21.0	-21.0	-23.0	-23.0	-2.0	-2.0	9.0	9.0
22 11	5.5	4.0	4.0	78.8	1.0	4.8	4.8	20.0	20.0	-18.5	-19.0	-21.5	-21.5	-6.5	-6.5	12.0	12.0
22 12	2.5	-4.0	6.0	78.7	1.0	-1.6	-1.6	25.5	26.5	-25.5	-26.5	-27.5	-28.5	6.0	6.5	4.0	3.5
22 13	5.5	-15.0	4.0	78.8	1.0	2.6	2.6	23.0	23.0	-22.5	-22.5	-25.0	-25.0	-2.0	-2.0	9.5	9.5
22 14	5.5	15.0	6.0	78.9	1.0	2.8	3.2	21.0	22.0	-22.5	-23.0	-22.5	-23.0	-3.0	-3.0	9.5	10.0
22 15	2.5	8.0	4.0	78.9	1.0	3.6	4.0	18.5	17.5	-17.5	-17.0	-20.0	-19.5	-3.5	-4.0	11.0	11.0
22 16	5.5	8.0	4.0	78.9	1.0	3.2	3.0	19.5	19.5	-18.5	-18.5	-21.0	-21.0	-4.0	-4.0	10.0	10.0
22 17	5.5	8.0	6.0	78.9	1.0	4.0	3.8	17.0	17.0	-16.0	-16.0	-18.5	-18.5	-6.0	-5.5	11.0	10.5
22 18	2.5	-15.0	4.0	78.8	1.0	2.2	2.2	22.5	23.0	-22.5	-23.0	-24.5	-25.0	-1.5	-1.0	8.5	8.5
22 19	5.5	-15.0	6.0	78.7	1.0	2.2	2.6	23.0	23.5	-23.0	-23.0	-25.0	-25.5	-2.0	-2.0	9.5	9.5
22 20	2.5	4.0	4.0	79.0	1.0	4.6	4.6	15.0	15.0	-13.5	-14.0	-16.0	-16.0	-6.5	-6.5	11.0	11.0
STANDARD				78.9	1.0	2.0	1.8	24.0	23.0	-23.5	-23.0	-26.0	-25.5	-1.0	-1.0	9.0	8.5
ZERO						0.0		0.5		0.0		0.0		0.0		-0.5	

SERIES 23

V SET	W INT	ALPHA	B DYN	B INT
3	2	105	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.4	3.0	-3.0	-2.2	25.0	25.0	-26.0	-26.0	-26.0	-26.0	8.5	8.5	0.0	0.0
23 1	5.5	-15.0	4.0	78.3	3.0	-2.6	-3.4	25.0	24.5	-26.0	-25.5	-26.0	-25.5	9.0	8.5	0.0	0.0
23 2	5.5	4.0	6.0	78.3	3.0	-0.8	-0.6	19.0	19.0	-19.5	-19.5	-20.0	-20.0	2.0	2.0	3.0	3.0
23 3	2.5	-4.0	4.0	78.3	3.0	-4.0	-4.4	26.0	26.5	-27.0	-28.0	-27.5	-28.0	10.5	11.0	-1.0	-1.0
23 4	5.5	-15.0	6.0	78.2	3.0	-3.0	-2.2	24.5	25.0	-25.5	-26.0	-26.0	-26.0	8.0	8.5	0.0	0.0
23 5	2.5	8.0	6.0	78.3	3.0	0.0	-0.2	17.0	16.5	-17.0	-17.0	-17.5	-17.5	2.5	2.5	2.5	2.5
23 6	5.5	4.0	4.0	78.5	3.0	-0.6	-1.0	22.0	22.0	-22.5	-22.5	-23.0	-23.0	4.0	4.0	2.5	2.5
23 7	5.5	8.0	6.0	78.5	3.0	-0.8	-0.8	19.0	19.5	-19.5	-20.0	-20.0	-20.0	3.5	3.5	2.5	2.5
23 8	2.5	4.0	6.0	78.4	3.0	0.2	0.6	11.5	11.5	-11.5	-12.0	-12.0	-12.5	-0.5	0.0	2.5	2.5
23 9	2.5	-4.0	6.0	78.4	3.0	-5.2	-5.0	28.5	28.5	-29.5	-30.0	-30.5	-30.5	13.0	13.0	-2.5	-3.0
23 10	5.5	15.0	4.0	78.3	3.0	-2.8	-2.2	24.5	24.5	-25.5	-25.5	-26.0	-26.0	8.0	8.0	1.0	1.0
23 11	2.5	4.0	4.0	78.5	3.0	0.4	0.2	17.0	16.5	-17.0	-17.0	-17.5	-17.5	2.0	2.0	3.0	3.0
23 12	2.5	15.0	6.0	78.5	3.0	-2.4	-2.6	23.0	23.0	-23.5	-23.5	-24.0	-24.0	7.5	8.0	0.5	0.5
23 13	5.5	15.0	6.0	78.5	3.0	-2.0	-2.8	23.0	23.0	-23.5	-23.5	-24.0	-24.0	7.0	7.0	0.5	0.5
23 14	5.5	-4.0	6.0	78.4	3.0	-6.0	-6.0	31.0	31.0	-32.0	-32.0	-33.0	-33.0	14.0	14.0	-3.0	-3.0
23 15	2.5	8.0	4.0	78.4	3.0	-1.2	-1.6	21.0	21.0	-21.0	-21.5	-21.0	-21.5	5.0	5.5	1.5	1.5
23 16	2.5	-15.0	4.0	78.5	3.0	-3.6	-3.4	25.0	24.5	-26.0	-25.5	-26.0	-25.5	9.0	8.5	-0.5	-0.5
23 17	5.5	8.0	4.0	78.4	3.0	-1.0	-1.6	22.0	21.0	-22.0	-21.5	-22.5	-22.0	5.0	5.0	2.0	2.0
23 18	2.5	-15.0	6.0	78.4	3.0	-3.0	-3.8	25.0	25.5	-26.0	-26.0	-26.0	-26.5	9.0	9.0	-0.5	-0.5
23 19	2.5	15.0	4.0	78.5	3.0	-2.6	-3.0	24.0	24.0	-24.5	-24.5	-25.0	-25.0	8.5	8.5	0.0	0.0
23 20	5.5	-4.0	4.0	78.5	3.0	-4.8	-4.4	29.5	29.5	-31.0	-31.0	-31.5	-31.5	12.0	11.5	-1.0	-1.0
STANDARD				78.5	3.0	-3.0	-3.4	26.5	26.0	-27.5	-27.0	-27.5	-27.0	9.0	8.5	0.0	0.0
ZERO						0.2		0.5		0.5		0.0		0.0		0.0	

SERIES 24

V SET	W INT	ALPHA	B DYN	B INT
1	4	105	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.2		0.5		0.5		0.0		0.0		0.0	
STANDARD				79.2	1.0	-2.8	-3.0	24.0	24.0	-24.0	-24.0	-25.5	-25.5	7.5	7.5	1.0	1.0
24 1	5.5	-15.0	6.0	79.2	1.0	-3.0	-2.8	24.0	24.0	-24.0	-24.0	-26.0	-25.5	7.5	7.5	1.0	1.0
24 2	5.5	15.0	6.0	79.1	1.0	-2.0	-2.0	21.0	21.0	-21.0	-21.0	-22.5	-22.0	5.5	5.5	1.0	1.0
24 3	2.5	-15.0	4.0	79.4	1.0	-3.4	-3.2	24.0	24.0	-24.0	-24.0	-25.0	-25.5	8.0	8.0	0.0	0.0
24 4	5.5	-4.0	4.0	79.2	1.0	-4.8	-4.2	29.0	28.0	-29.0	-28.0	-31.0	-30.0	11.5	11.0	-0.5	-0.5
24 5	5.5	4.0	4.0	79.2	1.0	-0.2	-0.2	18.5	18.0	-18.0	-18.0	-19.5	-19.5	1.0	1.0	4.0	4.0
24 6	2.5	15.0	6.0	79.2	1.0	-2.0	-1.8	20.0	20.0	-20.0	-20.0	-21.5	-21.5	6.0	6.0	2.5	2.5
24 7	5.5	8.0	6.0	79.1	1.0	-0.2	-0.2	16.0	15.5	-15.0	-15.0	-16.5	-16.0	0.5	0.5	4.0	3.5
24 8	2.5	-4.0	4.0	79.1	1.0	-4.8	-4.3	26.5	26.0	-26.5	-26.0	-28.5	-28.0	11.0	10.5	-1.0	-1.0
24 9	2.5	8.0	6.0	79.1	1.0	0.2	0.2	11.5	11.5	-11.0	-11.0	-12.0	-12.0	0.0	0.0	3.0	3.5
24 10	2.5	4.0	6.0	79.1	1.0	0.4	0.0	6.0	6.5	-5.5	-5.5	-6.5	-6.5	-1.5	-1.5	1.5	1.5
24 11	5.5	-15.0	4.0	79.0	1.0	-3.0	-2.8	23.0	24.0	-23.0	-24.0	-24.5	-25.5	7.0	7.5	1.0	1.0
24 12	5.5	15.0	4.0	79.1	1.0	-1.8	-2.2	21.0	21.0	-21.0	-21.0	-22.5	-22.0	5.5	5.5	1.5	1.5
24 13	5.5	8.0	4.0	79.1	1.0	-1.0	-1.0	18.5	18.5	-18.0	-18.0	-19.5	-19.5	3.0	3.0	3.0	3.0
24 14	2.5	4.0	4.0	79.1	1.0	0.2	0.2	12.0	12.0	-11.0	-11.0	-12.5	-12.0	0.5	0.0	3.0	3.0
24 15	5.5	-4.0	6.0	79.1	1.0	-7.0	-6.0	30.0	30.5	-31.0	-31.0	-32.5	-33.0	15.5	14.5	-3.5	-2.0
24 16	2.5	15.0	4.0	79.0	1.0	-2.0	-2.6	22.0	22.0	-22.0	-22.0	-23.5	-23.0	6.5	7.0	2.0	1.0
24 17	2.5	-4.0	6.0	79.1	1.0	-6.4	-5.6	28.5	28.5	-28.5	-28.5	-30.5	-30.5	15.5	14.0	-3.5	-2.0
24 18	2.5	-15.0	6.0	79.1	1.0	-2.8	-3.0	24.0	24.0	-23.5	-23.5	-24.5	-25.0	7.5	8.0	0.0	0.0
24 19	2.5	8.0	4.0	79.1	1.0	-0.6	-1.2	17.5	17.5	-16.5	-17.0	-18.0	-18.0	3.5	4.0	3.0	2.5
24 20	5.5	4.0	6.0	79.1	1.0	0.2	0.4	14.5	14.5	-13.5	-13.5	-15.0	-15.0	-1.0	-1.0	3.5	3.5
STANDARD				79.1	1.0	-2.8	-3.0	23.5	23.5	-23.5	-23.5	-25.0	-25.0	7.0	7.0	0.5	1.0
ZERO						0.0		0.5		0.5		0.0		0.0		0.0	

SERIES 25

V SET	W INT	ALPHA	B DYN	B INT
1	4	75	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						-0.1		0.3		-0.4		-0.5		0.0		0.0	
STANDARD				80.0	1.0	1.8	1.5	16.5	16.5	-14.0	-14.0	-20.5	-20.0	-5.0	-5.0	5.0	5.0
25 1	2.5	4.0	4.0	80.0	1.0	2.5	2.4	10.0	10.0	-7.0	-7.0	-14.5	-15.0	-6.5	-6.5	7.5	7.5
25 2	5.5	-15.0	6.0	79.9	1.0	2.0	1.8	16.5	16.5	-14.0	-14.0	-20.5	-20.5	-5.5	-5.5	6.0	6.0
25 3	5.5	15.0	4.0	79.9	1.0	2.0	1.4	15.0	15.0	-12.5	-13.0	-19.0	-19.0	-5.5	-5.0	6.0	6.0
25 4	2.5	15.0	6.0	79.8	1.0	2.0	2.0	14.0	14.0	-12.0	-12.0	-18.5	-18.0	-5.5	-5.0	6.5	7.0
25 5	5.5	-4.0	4.0	79.7	1.0	1.2	1.0	18.5	19.0	-17.0	-17.5	-22.5	-23.0	-4.0	-4.0	5.0	5.0
25 6	2.5	8.0	6.0	79.7	1.0	2.0	2.8	9.0	9.0	-6.0	-6.5	-12.5	-13.0	-5.5	-6.0	6.0	6.5
25 7	5.5	15.0	6.0	79.6	1.0	1.6	1.6	15.0	15.0	-12.5	-12.5	-19.0	-19.0	-5.0	-5.0	6.5	6.5
25 8	5.5	4.0	4.0	79.5	1.0	3.0	3.2	14.0	14.0	-11.0	-11.0	-19.0	-19.0	-7.0	-7.0	8.0	8.0
25 9	5.5	-4.0	6.0	79.6	1.0	0.2	0.0	20.0	20.5	-19.5	-19.5	-23.5	-23.5	-3.0	-3.0	3.5	3.5
25 10	2.5	8.0	4.0	79.6	1.0	2.6	2.2	12.5	12.5	-9.5	-9.5	-16.5	-16.5	-5.5	-5.5	7.0	7.0
25 11	5.5	4.0	6.0	79.4	1.0	3.2	3.2	13.0	13.0	-9.0	-9.0	-18.5	-19.0	-8.5	-8.5	9.0	9.5
25 12	2.5	-4.0	4.0	79.4	1.0	0.6	0.4	18.0	18.5	-17.5	-17.5	-21.0	-21.0	-2.5	-2.5	3.5	3.5
25 13	5.5	-15.0	4.0	79.5	1.0	2.0	1.8	16.0	16.5	-14.0	-14.0	-20.5	-20.5	-5.5	-5.5	6.5	6.5
25 14	2.5	-4.0	6.0	79.4	1.0	-0.8	-0.8	18.5	19.0	-19.0	-19.5	-21.0	-21.0	0.0	0.0	3.0	2.5
25 15	2.5	-15.0	4.0	79.3	1.0	1.6	1.8	16.0	16.5	-14.0	-14.0	-20.0	-20.5	-4.5	-5.0	6.0	6.0
25 16	2.5	4.0	6.0	79.3	1.0	2.0	2.4	7.0	7.0	-4.0	-4.0	-10.0	-10.0	-6.5	-6.5	6.0	6.0
25 17	2.5	-15.0	6.0	79.3	1.0	1.8	1.8	16.0	16.0	-14.0	-14.0	-20.0	-20.0	-5.0	-5.0	6.0	6.0
25 18	2.5	15.0	4.0	79.4	1.0	1.6	1.6	15.0	14.5	-12.5	-12.0	-18.5	-18.5	-5.0	-5.0	6.0	6.0
25 19	5.5	8.0	4.0	79.4	1.0	2.2	1.8	14.0	14.0	-11.5	-11.5	-18.0	-18.0	-5.5	-6.0	6.5	6.5
25 20	5.5	8.0	6.0	79.3	1.0	2.6	2.8	12.5	12.5	-9.5	-9.5	-17.0	-17.0	-6.5	-6.5	7.5	7.5
STANDARD				79.4	1.0	1.6	2.0	16.5	16.5	-14.0	-13.5	-20.0	-20.0	-5.5	-5.5	6.0	6.0
ZERO						0.0		0.5		0.0		-0.5		0.0		0.5	

SERIES 26

V SET	W INT	ALPHA	B DYN	B INT
3	2	75	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		-0.5		0.0		0.0		0.0	
STANDARD				79.3	2.8	-3.0	-3.2	19.0	19.0	-22.5	-22.0	-17.5	-17.5	4.5	4.5	-3.5	-3.5
26 1	5.5	8.0	4.0	79.3	2.8	-2.0	-2.0	17.0	16.5	-19.0	-18.5	-16.0	-16.0	2.5	2.5	-2.0	-2.0
26 2	5.5	-15.0	6.0	79.3	2.8	-2.8	-3.0	19.0	19.0	-22.0	-22.5	-17.5	-18.0	4.5	4.5	-4.0	-3.5
26 3	2.5	15.0	6.0	79.2	2.8	-2.0	-2.2	17.0	16.5	-19.0	-19.5	-16.0	-16.0	3.5	3.5	-3.0	-3.0
26 4	2.5	8.0	6.0	79.2	2.8	-1.0	-0.4	13.5	13.0	-14.0	-14.0	-13.5	-14.0	0.5	0.5	-0.5	-0.5
26 5	2.5	-4.0	4.0	79.0	2.8	-3.2	-4.0	19.5	20.0	-23.0	-23.0	-18.0	-18.0	5.5	5.5	-4.5	-5.0
26 6	5.5	-4.0	6.0	79.0	2.8	-4.8	-4.8	22.5	22.5	-27.5	-27.5	-20.0	-20.0	8.0	8.0	-6.5	-6.5
26 7	2.5	4.0	6.0	79.0	2.8	0.2	0.4	9.5	9.5	-9.0	-9.0	-10.0	-10.0	-2.0	-2.0	0.5	0.5
26 8	5.5	-4.0	4.0	79.0	2.8	-4.6	-3.6	21.5	21.5	-25.5	-25.5	-19.0	-19.5	6.5	6.5	-5.0	-5.0
26 9	2.5	-15.0	6.0	79.0	2.8	-2.8	-2.4	18.0	18.0	-22.0	-21.5	-16.5	-16.5	4.5	4.5	-4.0	-4.0
26 10	2.5	15.0	4.0	78.9	2.8	-2.2	-2.4	17.5	17.5	-20.0	-20.0	-16.0	-16.0	4.0	4.0	-3.5	-3.5
26 11	2.5	8.0	4.0	78.8	2.8	-1.6	-2.0	16.0	16.0	-18.0	-18.0	-15.0	-15.0	3.0	3.0	-2.5	-2.5
26 12	5.5	8.0	6.0	79.0	2.8	-1.0	-1.4	16.0	16.0	-17.0	-17.0	-15.5	-15.5	1.0	1.5	-1.0	-1.0
26 13	2.5	4.0	4.0	79.0	2.8	-0.2	-0.2	12.0	12.5	-13.0	-13.5	-12.5	-12.5	0.5	0.5	-0.5	-0.5
26 14	5.5	15.0	4.0	78.9	2.8	-2.0	-2.0	18.0	18.0	-21.0	-21.0	-17.0	-17.0	3.5	4.0	-3.5	-3.5
26 15	5.5	15.0	6.0	78.8	2.8	-2.2	-2.4	17.5	17.5	-20.5	-20.5	-16.5	-16.5	3.5	3.5	-3.0	-3.0
26 16	2.5	-4.0	6.0	78.8	2.8	-4.2	-4.6	21.0	21.0	-25.0	-25.0	-18.5	-18.5	7.0	7.0	-6.0	-6.0
26 17	5.5	4.0	6.0	78.4	2.8	-0.4	-0.4	16.0	16.0	-16.5	-16.5	-16.5	-16.5	0.0	0.0	-0.5	-0.5
26 18	2.5	-15.0	4.0	78.8	2.8	-2.8	-3.0	18.0	18.0	-21.0	-21.0	-16.0	-16.0	4.5	4.5	-4.0	-4.0
26 19	5.5	4.0	4.0	78.7	2.8	-1.0	-1.2	16.5	16.5	-18.5	-18.0	-16.5	-17.0	1.0	1.0	-1.0	-1.0
26 20	5.5	-15.0	4.0	78.5	2.8	-3.2	-2.8	18.5	18.5	-21.5	-22.0	-17.0	-17.0	4.0	4.0	-3.5	-3.5
STANDARD				78.4	2.8	-2.2	-3.0	19.0	18.5	-21.5	-21.5	-17.0	-17.0	4.0	4.0	-3.5	-3.5
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	

SERIES 27

V SET	W INT	ALPHA	B DYN	B INT
3	2	105	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		0.0		0.0	
STANDARD				78.6	2.9	3.2	3.4	25.5	25.5	-25.5	-25.5	-28.0	-28.0	-2.5	-2.5	12.0	12.0
27 1	5.5	4.0	6.0	78.6	2.9	5.2	5.4	21.0	21.0	-20.5	-20.5	-23.0	-23.0	-7.0	-7.0	13.0	13.5
27 2	2.5	4.0	6.0	78.6	2.9	4.2	4.2	13.0	13.0	-12.5	-12.5	-14.0	-14.0	-7.5	-7.5	10.5	11.0
27 3	2.5	-4.0	6.0	78.7	2.9	0.2	0.6	28.0	28.5	-28.0	-28.5	-30.5	-31.0	2.5	0.2	-0.0	8.0
27 4	2.5	8.0	6.0	78.9	2.9	3.8	3.0	17.0	17.0	-17.0	-17.0	-19.0	-19.0	-5.5	-5.5	11.0	11.0
27 5	2.5	4.0	4.0	78.7	2.9	6.0	5.4	17.5	18.0	-17.5	-17.5	-20.0	-20.0	-7.0	-7.0	13.5	13.0
27 6	2.5	-15.0	4.0	78.8	2.9	2.6	3.0	24.0	24.5	-24.0	-24.0	-26.5	-26.5	-2.0	-2.5	10.5	10.5
27 7	5.5	15.0	4.0	78.6	2.9	4.0	3.0	24.0	24.0	-23.5	-23.5	-26.0	-26.0	-3.0	-3.0	11.5	11.5
27 8	2.5	15.0	6.0	78.8	2.9	3.4	3.2	22.5	22.0	-22.5	-22.0	-24.5	-24.0	-3.0	-3.0	11.5	11.0
27 9	5.5	-4.0	4.0	78.8	2.9	2.5	2.2	27.5	28.0	-27.0	-28.0	-30.0	-31.0	-1.0	-1.0	10.5	11.0
27 10	2.5	-15.0	6.0	78.8	2.9	2.8	3.0	24.0	24.5	-24.0	-24.0	-27.0	-26.5	-2.5	-2.0	10.5	10.5
27 11	2.5	-4.0	4.0	78.6	2.9	1.4	1.4	26.5	26.0	-26.5	-26.0	-29.0	-28.5	0.0	0.0	9.0	9.5
27 12	2.5	15.0	4.0	78.5	2.9	2.5	3.0	23.0	23.0	-23.0	-22.5	-25.0	-25.0	-2.5	-2.5	11.0	10.5
27 13	5.5	8.0	4.0	78.6	2.9	3.8	4.4	22.0	21.5	-22.0	-21.5	-24.0	-24.0	-4.0	-4.0	12.0	12.0
27 14	5.5	-15.0	6.0	78.6	2.9	2.8	3.0	25.0	25.0	-25.0	-25.0	-27.5	-27.5	-2.5	-2.5	11.5	11.0
27 15	5.5	-15.0	4.0	78.6	2.9	2.4	3.2	25.0	25.0	-25.0	-25.0	-27.5	-27.5	-3.0	-3.0	11.5	11.0
27 16	2.5	8.0	4.0	78.6	2.9	3.6	3.8	20.5	20.5	-20.0	-20.0	-22.0	-22.0	-4.0	-4.0	11.0	11.0
27 17	5.5	4.0	4.0	78.8	2.9	4.6	4.4	23.0	23.0	-22.5	-22.5	-25.0	-25.0	-6.0	-6.0	13.5	13.5
27 18	5.5	-4.0	6.0	79.0	2.9	1.4	1.4	29.0	29.0	-29.0	-29.0	-32.0	-32.0	1.0	1.0	9.0	9.0
27 19	5.5	8.0	6.0	78.7	2.9	4.8	4.2	20.5	20.5	-20.0	-20.0	-22.5	-22.0	-5.5	-5.5	12.0	12.0
27 20	5.5	15.0	6.0	78.7	2.9	2.6	3.2	23.5	23.5	-23.0	-23.5	-25.5	-22.5	-3.5	-3.0	11.0	11.5
STANDARD				78.6	2.9	3.2	2.8	26.5	27.0	-26.5	-26.5	-29.0	-29.5	-3.0	-3.0	12.0	12.0
ZERO						0.1		0.5		0.0		0.0		-0.5		0.0	

SERIES 28

V SET	W INT	ALPHA	B DYN	B INT
1	2	75	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.1		0.0		0.0		0.0		-0.5		0.0	
STANDARD				79.3	1.0	-2.6	-2.4	16.5	16.5	-19.0	-19.0	-15.5	-15.5	3.5	3.5	-3.5	-3.5
28 1	2.5	4.0	6.0	79.3	1.0	0.6	0.6	9.0	8.5	-8.0	-8.0	-9.5	-9.5	-3.0	-3.0	1.0	1.0
28 2	2.5	-4.0	4.0	79.0	1.0	-3.4	-3.4	18.0	18.0	-21.5	-21.5	-16.5	-16.5	4.5	4.5	-4.0	-4.0
28 3	2.5	8.0	6.0	78.9	1.0	-0.8	-1.2	12.5	12.5	-13.5	-13.5	-13.0	-13.0	0.0	0.0	0.0	-0.5
28 4	2.5	4.0	4.0	79.0	1.0	-0.4	-0.4	11.0	11.0	-11.5	-11.5	-12.0	-12.0	-1.0	-1.0	0.5	0.5
28 5	2.5	-15.0	6.0	79.2	1.0	-2.6	-2.8	16.0	16.5	-19.0	-19.0	-15.5	-15.5	3.0	3.0	-3.0	-3.0
28 6	5.5	8.0	6.0	79.3	1.0	-1.6	-1.2	14.0	14.0	-15.5	-15.5	-14.0	-13.5	1.0	1.0	-1.0	-1.0
28 7	5.5	-4.0	4.0	79.3	1.0	-3.0	-3.6	18.5	18.5	-22.0	-22.0	-17.0	-17.0	4.5	4.5	-4.0	-4.0
28 8	2.5	8.0	4.0	79.1	1.0	-1.8	-2.0	15.0	15.0	-17.0	-17.0	-14.5	-14.5	2.0	2.0	-2.0	-2.0
28 9	2.5	15.0	4.0	79.2	1.0	-2.6	-2.4	16.0	16.0	-19.0	-19.0	-15.0	-15.0	3.0	3.0	-3.0	-3.0
28 10	5.5	15.0	4.0	79.1	1.0	-2.3	-2.4	16.5	16.5	-18.5	-19.0	-15.5	-15.5	3.0	2.5	-2.5	-2.5
28 11	5.5	-15.0	4.0	79.1	1.0	-2.5	-2.2	16.5	16.5	-19.0	-19.0	-15.5	-15.5	3.0	3.0	-3.0	-3.0
28 12	5.5	4.0	6.0	79.1	1.0	-0.5	-0.6	13.5	13.5	-14.0	-14.0	-14.5	-14.0	-1.0	-1.0	0.5	0.5
28 13	2.5	15.0	6.0	79.0	1.0	-2.5	-2.8	16.0	16.0	-19.0	-19.0	-15.5	-15.5	3.5	3.5	-3.0	-3.0
28 14	5.5	15.0	6.0	79.0	1.0	-2.6	-2.4	16.0	16.0	-18.5	-18.5	-15.0	-15.0	3.0	3.0	-2.5	-2.5
28 15	5.5	4.0	4.0	79.1	1.0	-1.4	-1.0	14.0	14.0	-15.5	-15.5	-14.5	-14.5	0.5	0.5	-1.0	-1.0
28 16	5.5	-4.0	6.0	79.0	1.0	-4.2	-4.4	19.0	19.0	-23.5	-24.0	-17.5	-17.0	6.0	6.0	-5.5	-5.5
28 17	5.5	8.0	4.0	79.0	1.0	-2.2	-2.2	14.5	15.0	-17.0	-17.0	-14.0	-14.0	2.0	2.0	-2.0	-2.0
28 18	5.5	-15.0	6.0	78.8	1.0	-2.8	-2.6	16.5	16.5	-19.0	-19.0	-16.0	-16.0	3.0	3.0	-3.0	-3.0
28 19	2.5	-15.0	4.0	78.9	1.0	-2.4	-2.6	16.0	16.5	-19.0	-19.0	-15.0	-15.0	3.0	3.0	-3.0	-3.0
28 20	2.5	-4.0	6.0	79.0	1.0	-4.0	-4.0	18.5	18.5	-23.0	-22.5	-17.0	-16.5	6.0	6.0	-5.5	-5.5
STANDARD				79.3	1.0	-2.2	-2.6	16.5	16.5	-19.0	-19.0	-15.0	-15.0	3.5	3.5	-3.5	-3.5
ZERO						0.1		0.0		0.0		-0.5		-0.5		0.0	

SERIES 29

V SET	W INT	ALPHA	B DYN	B INT
1	4	105	75	105

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.2		0.0		0.0		0.5		0.0		0.0	
STANDARD				79.1	1.0	-2.2	-2.4	24.0	24.0	-24.5	-25.0	-24.0	-24.5	8.0	8.0	1.0	1.0
29 1	5.5	8.0	4.0	79.3	1.0	-0.4	-0.4	20.0	20.0	-20.5	-20.5	-20.5	-20.5	3.5	4.0	3.5	3.0
29 2	2.5	8.0	6.0	79.3	1.0	0.5	0.2	12.5	12.5	-12.0	-12.5	-12.0	-12.5	1.0	1.0	3.0	3.0
29 3	2.5	15.0	4.0	79.3	1.0	-2.0	-1.8	23.0	22.5	-24.0	-23.5	-24.0	-23.5	7.5	7.5	1.5	1.5
29 4	2.5	15.0	6.0	79.3	1.0	-1.6	-1.0	21.0	21.0	-21.5	-21.5	-21.5	-21.0	6.5	6.0	2.0	2.5
29 5	2.5	8.0	4.0	79.3	1.0	-0.4	-0.4	18.0	18.0	-18.5	-18.0	-18.0	-18.0	4.0	4.0	3.0	3.0
29 6	2.5	-4.0	4.0	79.0	1.0	-4.8	-4.8	27.0	26.5	-28.0	-28.0	-28.0	-27.5	12.0	12.5	-1.5	-1.5
29 7	5.5	-15.0	4.0	79.0	1.0	-2.2	-2.4	23.0	23.5	-24.0	-24.0	-24.0	-24.0	7.5	7.5	1.0	1.0
29 8	2.5	-15.0	4.0	79.1	1.0	-2.8	-2.6	23.0	23.5	-24.0	-24.5	-24.0	-24.0	8.5	8.5	0.5	0.5
29 9	2.5	-4.0	6.0	78.9	1.0	-7.8	-7.4	29.0	29.0	-31.0	-31.0	-31.0	-31.0	16.0	15.5	-5.5	-5.0
29 10	2.5	4.0	6.0	78.9	1.0	1.0	0.8	7.0	7.0	-7.0	-7.0	-6.5	-6.5	-1.0	-1.0	2.0	2.0
29 11	2.5	4.0	4.0	78.7	1.0	0.6	1.0	13.0	13.0	-13.0	-13.0	-13.0	-12.5	0.5	0.5	3.5	3.5
29 12	2.5	-15.0	6.0	78.8	1.0	-2.6	-2.8	23.5	23.5	-24.0	-24.5	-23.5	-24.0	8.5	8.5	0.5	0.0
29 13	5.5	8.0	6.0	78.8	1.0	0.4	0.6	14.0	14.5	-14.5	-15.0	-15.0	-14.5	1.0	1.5	4.0	4.0
29 14	5.5	-4.0	4.0	79.0	1.0	-4.8	-4.2	28.5	28.5	-29.5	-29.0	-29.5	-29.0	12.5	12.0	-1.5	-1.0
29 15	5.5	4.0	4.0	78.9	1.0	0.2	0.2	20.0	20.0	-20.5	-20.5	-20.5	-20.5	2.0	2.0	4.0	4.0
29 16	5.5	4.0	6.0	78.9	1.0	0.8	0.8	16.5	16.0	-16.5	-16.0	-16.5	-16.0	0.0	0.0	4.0	4.0
29 17	5.5	15.0	6.0	79.1	1.0	-1.4	-1.2	22.0	22.0	-23.0	-22.5	-22.5	-22.0	6.0	5.5	2.0	2.0
29 18	5.5	-4.0	6.0	79.1	1.0	-7.0	-6.8	31.0	31.0	-33.0	-33.0	-32.5	-32.5	17.0	17.0	-4.0	-3.5
29 19	5.5	15.0	4.0	79.0	1.0	-1.6	-1.8	22.5	22.5	-23.0	-23.5	-23.0	-23.0	6.5	6.5	1.5	1.5
29 20	5.5	-15.0	6.0	79.0	1.0	-2.2	-2.4	23.0	23.0	-23.5	-24.0	-23.5	-23.5	7.5	7.5	1.0	1.0
STANDARD				78.9	1.0	-2.2	-2.6	23.5	23.5	-24.0	-24.0	-23.5	-24.0	7.5	7.5	1.0	1.0
ZERO						0.2		0.0		0.0		0.5		-0.5		0.0	

SERIES 30

V SET	W INT	ALPHA	B DYN	B INT
3	2	75	75	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.2		0.0		0.0		0.0		0.5		0.0	
STANDARD				78.6	3.0	-2.6	-2.6	17.5	17.5	-21.0	-21.0	-17.0	-17.0	4.0	4.0	-4.0	-4.0
30 1	2.5	8.0	6.0	78.7	3.0	-0.2	0.0	13.0	13.0	-13.5	-13.5	-14.0	-14.0	0.0	0.0	-0.5	-0.5
30 2	5.5	15.0	6.0	78.8	3.0	-1.8	-2.0	16.0	16.5	-19.0	-19.0	-16.5	-16.5	3.0	3.0	-2.5	-2.5
30 3	5.5	-4.0	6.0	78.8	3.0	-3.8	-4.2	21.0	21.0	-26.0	-26.0	-20.5	-20.5	7.0	7.0	-5.5	-6.0
30 4	5.5	15.0	4.0	78.7	3.0	-2.2	-1.8	17.0	17.0	-20.0	-19.5	-17.0	-17.0	3.0	3.5	-3.0	-3.0
30 5	5.5	8.0	4.0	78.6	3.0	-1.0	-1.4	16.0	15.5	-17.5	-17.5	-16.0	-16.0	2.0	2.0	-2.0	-2.0
30 6	5.5	8.0	6.0	78.5	3.0	-1.0	-0.5	14.5	14.0	-16.0	-16.0	-15.5	-16.0	1.0	1.0	-1.0	-1.0
30 7	2.5	15.0	6.0	78.6	3.0	-1.6	-1.4	15.0	15.5	-18.0	-18.0	-15.5	-15.5	3.0	3.0	-2.5	-3.0
30 8	2.5	-4.0	6.0	78.7	3.0	-4.2	-4.2	20.5	20.5	-25.0	-25.0	-19.0	-19.0	7.0	7.0	-6.0	-6.0
30 9	5.5	-15.0	6.0	78.6	3.0	-2.6	-2.2	18.0	18.0	-21.5	-21.5	-18.0	-18.0	4.0	4.0	-3.5	-3.5
30 10	5.5	-4.0	4.0	78.5	3.0	-3.4	-3.6	20.0	20.0	-24.0	-24.0	-19.5	-19.5	5.5	5.5	-4.5	-4.5
30 11	2.5	4.0	6.0	78.6	3.0	1.2	0.8	9.0	9.0	-9.0	-9.0	-11.5	-11.5	-2.0	-2.0	0.5	0.5
30 12	5.5	4.0	6.0	78.7	3.0	0.0	-0.4	14.5	14.5	-15.5	-16.0	-16.5	-16.5	-0.5	-0.5	0.0	0.0
30 13	2.5	15.0	4.0	78.5	3.0	-2.0	-2.0	16.0	16.0	-19.0	-19.0	-16.0	-16.0	3.5	3.5	-3.5	-3.5
30 14	2.5	-15.0	4.0	78.6	3.0	-2.2	-2.2	17.5	17.5	-21.0	-21.0	-17.0	-16.5	4.0	4.0	-4.0	-4.0
30 15	5.5	4.0	4.0	78.7	3.0	-1.0	-0.6	15.5	15.5	-17.0	-17.0	-16.5	-16.5	1.0	1.0	-1.0	-1.0
30 16	2.5	-15.0	6.0	78.7	3.0	-2.4	-2.5	17.0	17.0	-21.0	-21.0	-17.0	-17.0	4.0	4.0	-4.0	-4.0
30 17	2.5	-4.0	4.0	78.6	3.0	-3.2	-3.3	19.0	19.0	-23.0	-23.0	-18.5	-18.5	5.5	5.0	-4.5	-4.5
30 18	2.5	4.0	4.0	78.6	3.0	0.2	-0.3	12.0	12.0	-12.5	-13.0	-13.5	-13.5	0.0	0.0	0.0	0.0
30 19	5.5	-15.0	4.0	78.7	3.0	-2.6	-2.4	18.0	18.0	-21.5	-21.5	-18.5	-18.5	4.0	4.0	-3.5	-3.5
30 20	2.5	8.0	4.0	78.7	3.0	-1.4	-1.2	14.5	14.5	-17.0	-17.0	-15.5	-15.5	2.5	2.5	-2.5	-2.5
STANDARD				78.7	3.0	-2.0	-2.2	17.0	17.0	-21.0	-21.0	-17.0	-17.0	4.0	4.0	-4.0	-4.0
ZERO						0.2		-0.5		0.0		-1.0		0.0		0.0	

SERIES 31

V SET	W INT	ALPHA	B DYN	B INT
3	4	105	105	75

TEST	X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO						0.0		0.0		0.0		0.0		-0.5		0.0	
STANDARD				79.3	3.0	3.0	2.6	25.0	24.5	-25.5	-25.5	-28.0	-28.0	-2.5	-3.0	11.5	12.0
31 1	5.5	15.0	6.0	79.3	3.0	4.6	4.4	21.0	21.5	-22.0	-22.0	-24.0	-24.0	-4.5	-5.0	13.0	13.0
31 2	2.5	-15.0	4.0	79.3	3.0	2.4	1.8	23.5	23.5	-24.5	-24.5	-26.5	-26.5	-2.0	-2.5	10.5	10.5
31 3	5.5	-4.0	4.0	79.3	3.0	1.5	1.8	30.0	30.0	-30.5	-30.5	-33.0	-33.0	1.0	1.0	9.5	9.5
31 4	2.5	4.0	6.0	79.3	3.0	3.8	3.2	8.0	7.5	-8.0	-8.0	-8.5	-8.5	-6.5	-6.5	7.0	7.0
31 5	5.5	15.0	4.0	79.2	3.0	3.8	3.4	21.5	22.0	-22.5	-22.5	-24.0	-24.0	-4.0	-4.0	11.5	11.5
31 6	2.5	8.0	4.0	79.1	3.0	4.0	4.4	16.5	17.0	-17.0	-17.0	-18.5	-18.5	-5.0	-5.0	11.5	11.5
31 7	2.5	15.0	6.0	79.1	3.0	3.0	3.6	18.0	18.0	-18.0	-18.0	-19.5	-19.5	-4.5	-4.0	11.5	11.5
31 8	2.5	-4.0	6.0	79.2	3.0	-1.8	-1.2	29.0	29.0	-30.5	-30.5	-32.5	-32.5	6.5	6.5	5.5	5.0
31 9	5.5	4.0	6.0	79.2	3.0	5.4	6.0	17.5	17.5	-18.0	-18.0	-20.5	-20.0	-8.5	-9.0	13.5	13.5
31 10	5.5	8.0	4.0	79.1	3.0	4.4	4.4	19.5	19.5	-20.0	-20.5	-22.5	-22.5	-6.0	-5.5	12.5	12.5
31 11	2.5	4.0	4.0	78.9	3.0	4.4	4.6	13.5	13.5	-13.5	-14.0	-15.5	-15.5	-6.5	-6.5	11.5	11.5
31 12	5.5	-15.0	4.0	79.0	3.0	2.5	2.6	24.0	24.5	-25.0	-25.0	-27.0	-27.5	-2.5	-3.0	11.0	11.5
31 13	5.5	4.0	4.0	79.0	3.0	5.6	6.0	20.5	20.5	-21.0	-21.0	-23.5	-23.0	-8.0	-8.0	14.5	15.0
31 14	2.5	-4.0	4.0	78.9	3.0	0.5	0.2	27.0	26.5	-28.0	-28.0	-30.0	-30.0	2.0	2.0	8.0	8.0
31 15	5.5	-15.0	6.0	78.8	3.0	2.8	2.2	24.0	24.0	-25.0	-25.0	-27.5	-27.5	-2.5	-2.5	11.5	11.5
31 16	5.5	8.0	6.0	78.8	3.0	4.8	5.2	17.5	17.5	-18.0	-18.0	-19.5	-20.0	-8.0	-8.0	13.5	13.5
31 17	5.5	-4.0	6.0	78.9	3.0	-0.6	-1.6	31.5	31.5	-33.0	-33.0	-35.0	-35.0	5.0	5.5	6.5	6.0
31 18	2.5	-15.0	6.0	79.0	3.0	3.0	2.8	23.5	23.0	-24.0	-24.0	-26.0	-26.0	-2.5	-2.5	10.5	10.5
31 19	2.5	8.0	6.0	79.1	3.0	5.0	4.2	11.5	11.5	-11.5	-11.5	-13.0	-12.5	-7.0	-7.0	9.5	10.5
31 20	2.5	15.0	4.0	79.2	3.0	4.0	2.8	21.0	20.5	-21.0	-21.0	-23.0	-23.0	-3.5	-3.5	12.0	12.0
STANDARD				79.3	3.0	2.6	2.6	23.5	23.5	-24.0	-24.0	-26.0	-26.0	-2.5	-2.5	10.5	10.5
ZERO						0.0		0.0		0.0		0.5		-0.5		0.0	

SERIES 32

V SET	W INT	ALPHA	B DYN	B INT
3	4	105	75	105

TEST		X	Y	D INT	DEN	V ACT	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6
ZERO							0.0		0.0		0.0		0.0		-0.5		0.0	
STANDARD					79.2	3.0	-3.0	-3.6	24.5	24.5	-26.0	-26.5	-26.0	-26.0	8.5	8.5	0.5	0.5
32	1	5.5	8.0	4.0	79.2	3.0	-0.2	-0.4	20.5	20.0	-21.5	-21.5	-22.0	-21.5	3.0	3.0	3.5	3.5
32	2	5.5	15.0	4.0	79.2	3.0	-1.4	-1.4	22.5	22.5	-24.0	-24.0	-23.5	-23.5	6.0	6.0	2.0	2.0
32	3	5.5	-4.0	4.0	79.2	3.0	-5.6	-5.4	31.5	31.0	-34.0	-34.0	-34.0	-33.5	14.5	14.0	-2.0	-1.5
32	4	2.5	-15.0	4.0	79.1	3.0	-3.0	-3.5	23.5	24.0	-25.5	-25.5	-25.0	-25.0	8.5	9.0	0.0	0.0
32	5	5.5	4.0	6.0	78.9	3.0	0.6	0.4	17.5	17.5	-19.0	-19.0	-19.0	-19.0	1.0	1.0	3.5	3.5
32	6	2.5	-4.0	6.0	78.8	3.0	-8.0	-7.4	32.0	31.0	-34.0	-33.0	-34.5	-33.5	19.5	17.5	-5.5	-4.5
32	7	2.5	4.0	6.0	79.0	3.0	0.8	0.6	6.5	6.5	-7.0	-7.0	-6.5	-6.5	-1.0	-1.0	1.5	1.5
32	8	2.5	15.0	4.0	79.0	3.0	-2.0	-1.2	21.0	20.5	-22.5	-22.0	-22.0	-21.5	6.0	6.0	1.5	1.5
32	9	2.5	8.0	6.0	78.9	3.0	0.2	0.6	10.5	10.0	-11.0	-11.0	-11.0	-11.0	0.0	0.0	2.5	2.5
32	10	5.5	15.0	6.0	78.8	3.0	-0.5	-1.0	21.0	21.0	-22.5	-22.5	-22.5	-22.5	3.5	4.0	3.5	3.5
32	11	2.5	15.0	6.0	79.0	3.0	-1.2	-1.0	17.5	17.5	-19.0	-19.0	-18.5	-18.5	4.5	4.0	2.0	2.5
32	12	2.5	4.0	4.0	79.2	3.0	0.5	0.2	12.0	12.0	-13.0	-13.0	-12.5	-12.5	1.0	1.0	3.0	2.5
32	13	2.5	-4.0	4.0	79.2	3.0	-5.0	-5.2	28.5	28.5	-31.0	-31.0	-31.0	-31.0	12.5	12.5	-2.0	-1.5
32	14	2.5	-15.0	6.0	79.3	3.0	-3.6	-4.5	24.0	24.0	-26.0	-26.0	-25.5	-25.5	9.0	9.0	0.0	0.0
32	15	5.5	-15.0	4.0	79.0	3.0	-3.2	-3.2	25.0	24.5	-27.5	-27.0	-27.0	-26.0	8.5	8.5	0.5	0.5
32	16	2.5	8.0	4.0	78.9	3.0	-1.0	-1.2	16.5	16.5	-17.5	-17.5	-17.0	-17.0	3.0	3.0	3.0	3.0
32	17	5.5	4.0	4.0	79.0	3.0	-0.2	-0.8	21.5	21.5	-23.0	-23.5	-23.0	-23.5	3.0	2.5	3.5	4.0
32	18	5.5	8.0	6.0	78.8	3.0	1.0	0.4	17.5	17.5	-18.5	-18.5	-18.5	-18.5	0.0	0.0	4.0	4.0
32	19	5.5	-4.0	6.0	78.8	3.0	-9.0	-10.0	35.0	36.0	-38.5	-40.0	-38.5	-39.5	21.0	22.5	-6.0	-7.0
32	20	5.5	-15.0	6.0	79.0	3.0	-3.2	-2.8	25.0	24.5	-27.0	-26.5	-26.5	-26.0	8.5	8.0	0.0	0.0
STANDARD					79.0	3.0	-2.2	-3.2	25.0	25.0	-26.5	-26.5	-26.0	-26.0	8.5	8.5	0.0	0.0
ZERO							0.0		0.0		0.0		0.0		-0.5		0.0	

VITA

Tom Shepherd Chisholm

Candidate for the Degree of

Doctor of Philosophy

Thesis: THREE-DIMENSIONAL INTERFERENCE BETWEEN TWO TILLAGE TOOLS

Major Field: Agricultural Engineering

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