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Technical Report

DECISION TREES FOR MTM APPLICATION

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The author wishes to express his appreciation to the MTM Association in making this research possible, and in particular to John E. Mabry, the Staff Engineer of the MTM Association for his technical assistance in developing decision models.

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CHAPTER 1

INTRODUCTION

Methods-Time Measurement (MTM) is a well-known predetermined time system for work study and measurement of manual portions of any job. The correct application of MTM data requires precise identification of the basic motions and subsequent selection of time values from the MTM data card.*

During the last few years several attempts have been made to aid the application of MTM system to industrial operations. One such attempt was an approach towards binary decision models first introduced in the "MTM-2 Student Manual," published by MTM Association of the United Kingdom, in July 1965. The work in this direction was continued by Professor Walton M. Hancock and this paper is an extension of the same.

The purpose of this paper is to document the decision process, involved in the correct identification of MTM motions, in the form of decision trees. The decision model developed in this paper gives an explicit definition of the motions using binary decisions (yes-no type).

Åberg's (7.00)** study indicated the most frequently occurring motions in various types of industries, e.g., type A—medium heavy machine production, type B—medium heavy assembly work, etc. Based on his data for industry type

*MTM data card: published by MTM Association for Standards and Research, Ann Arbor, Michigan, which lists basic motion classifications with corresponding standard times in a tabular form.

**Numbers in parentheses refer to List of References at the end of this thesis.

"B", the decision models have been developed such that, the most frequently occurring motions are the first to be identified resulting in minimum total decision time by the applicator of the system.

Throughout this study heavy reliance has been placed on "Application Training Course Manual" (1.00), published by the MTM Association for Standards and Research, Ann Arbor, Michigan, 1964, for most motion descriptions and the associated "rules of thumb." However, additional references (listed in the references) were consulted whenever the manual did not contain the required information.

Chapter 2 of this paper presents the main tree for arriving at the basic motion, e.g., Reach, Move, Position, etc.

Chapters 3 through 13 contain the decision trees for individual motions taking into consideration the effects of all the variables that are found to determine the type of motion.

Chapter 14 contains the decision trees for simultaneous and combined motions.

Chapter 15 contains a discussion of some of the MTM motions and the suggestions for improvement.

Chapter 16 contains the conclusions together with a discussion of topics for potential further study.

Appendix A contains a statistical analysis which demonstrates the possibility of optimizing the decision models from the standpoint of time required to arrive at the proper decisions for body, leg, and foot motions.

Appendix B contains a description of the test conducted to verify the exactness of the models and the conclusions thereof.

CHAPTER 2

MAIN TREE

It is a standard practice in computer programming to have a main program which then calls different subroutines for necessary details. Similarly, in these decision models one will always have to start with the main tree which leads to the individual motion trees for case analysis.

The purpose of the main tree (Fig. 1) is to identify the basic motion as per the MTM terminology. Therefore, to analyze any motion pattern, one will first refer to the main tree to arrive at the correct basic motion name from the MTM terminology representing the motion under consideration.

Åberg (7.00) has found that in manual industrial operations, certain basic motions occur more frequently than others. He divided the industries into five different categories—A through E. In this paper industry B, "medium heavy assembly work," has been arbitrarily selected for the development of the decision trees. It is asserted that the total decision time of the applicator will be minimized if the decisions are developed as a function of the frequency of occurrence of the basic motions with the highest frequency first. Table I gives the frequency of occurrence of basic motions for this industry as given by Åberg (7.00). A detailed discussion of this has been presented in Appendix A. Figure 2 is a schematic representation of the basic motions using Åberg's industry B.

TABLE I

FREQUENCY OF OCCURRENCE OF BASIC MOTIONS FOR INDUSTRY B ACCORDING TO ÅBERG (7.00)

Motion Type	Frequency of Occurrence
Reach	209
Move	482
Turn	6
Apply Pressure	121
Grasp	318
Position	187
Release	170
Disengage	30
Eye Motions	5
Body Motions	85
Total	1,613

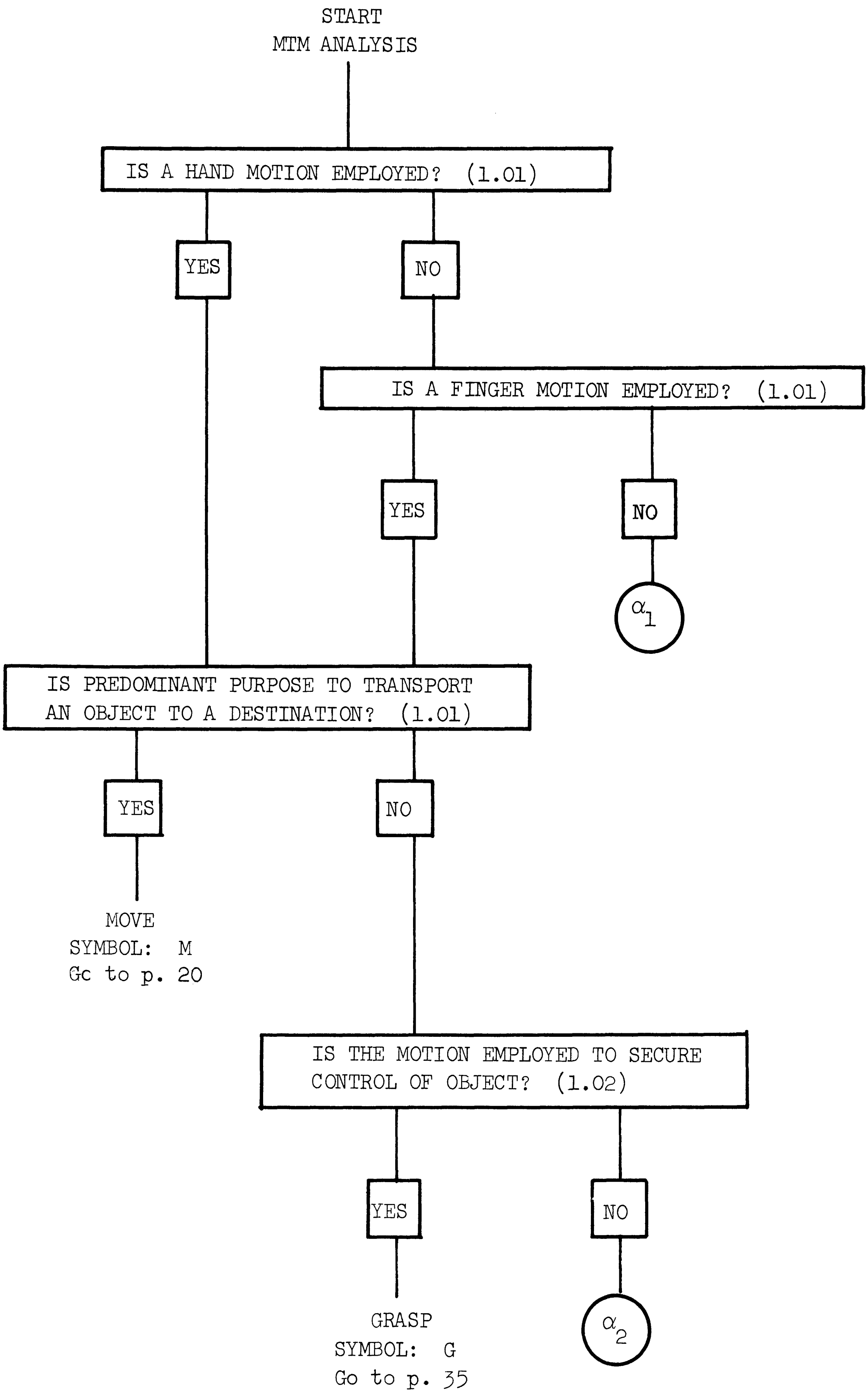


Fig. 1. Main tree (for determining the basic motion name).

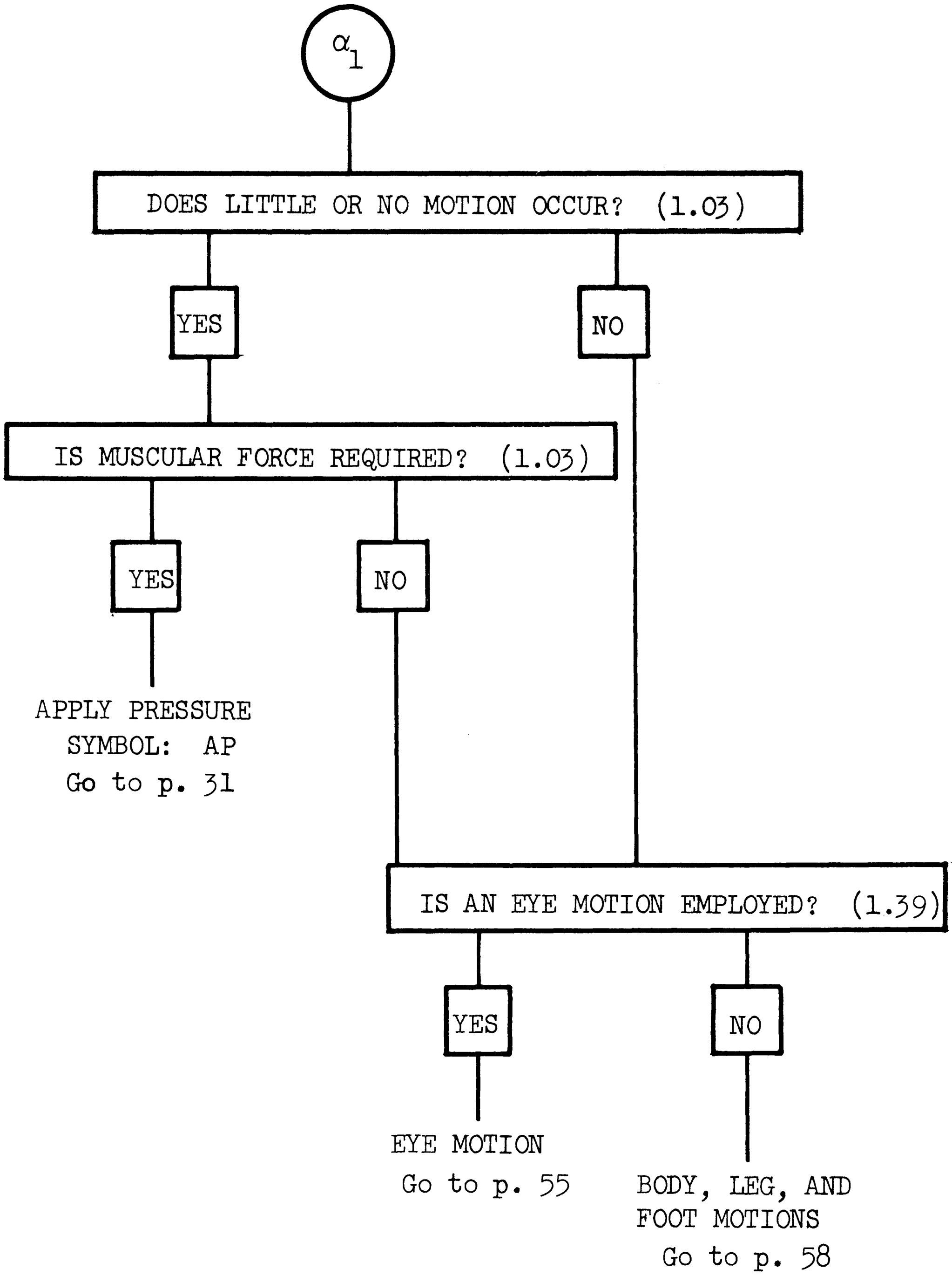


Fig. 1. (Continued).

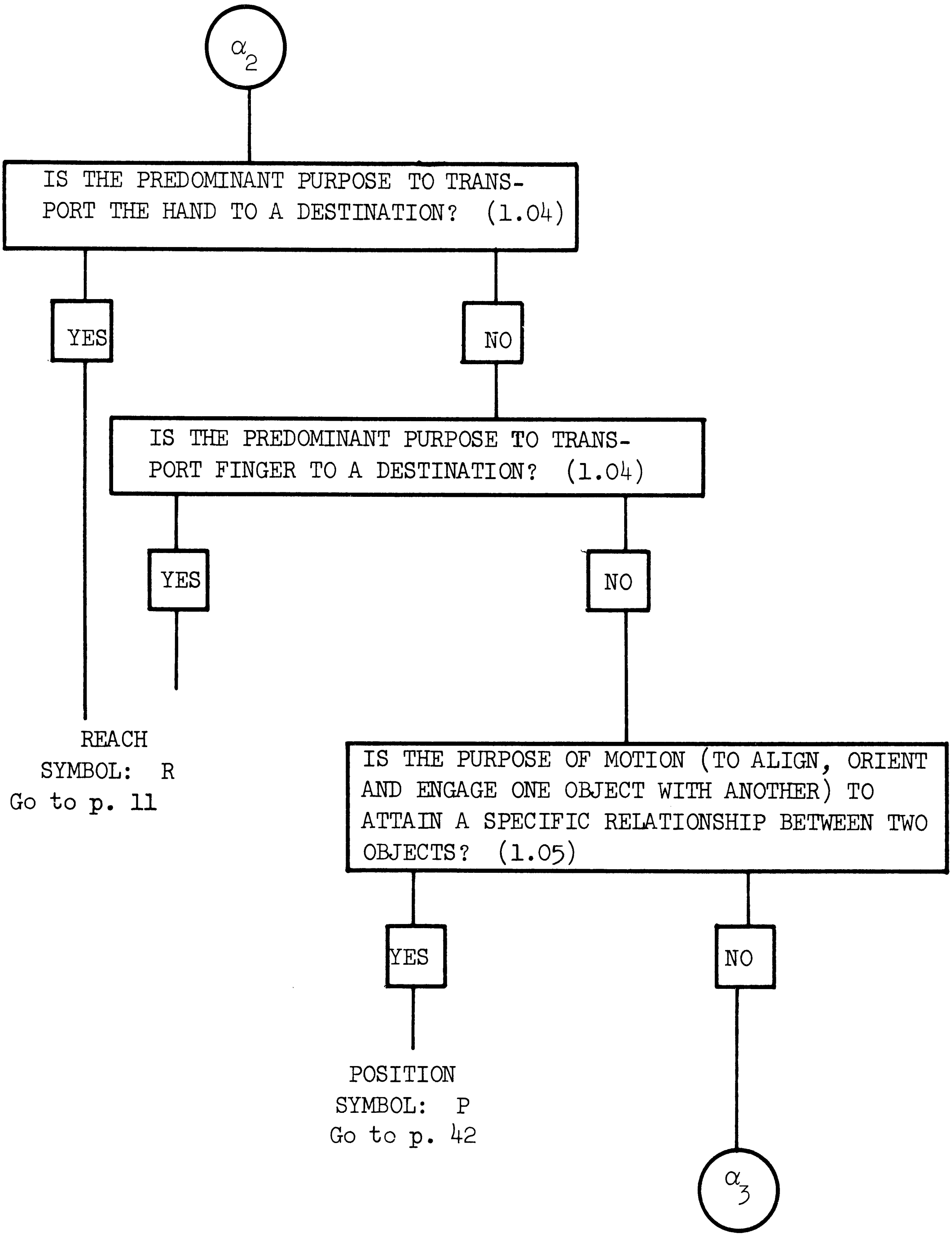


Fig. 1. (Continued).

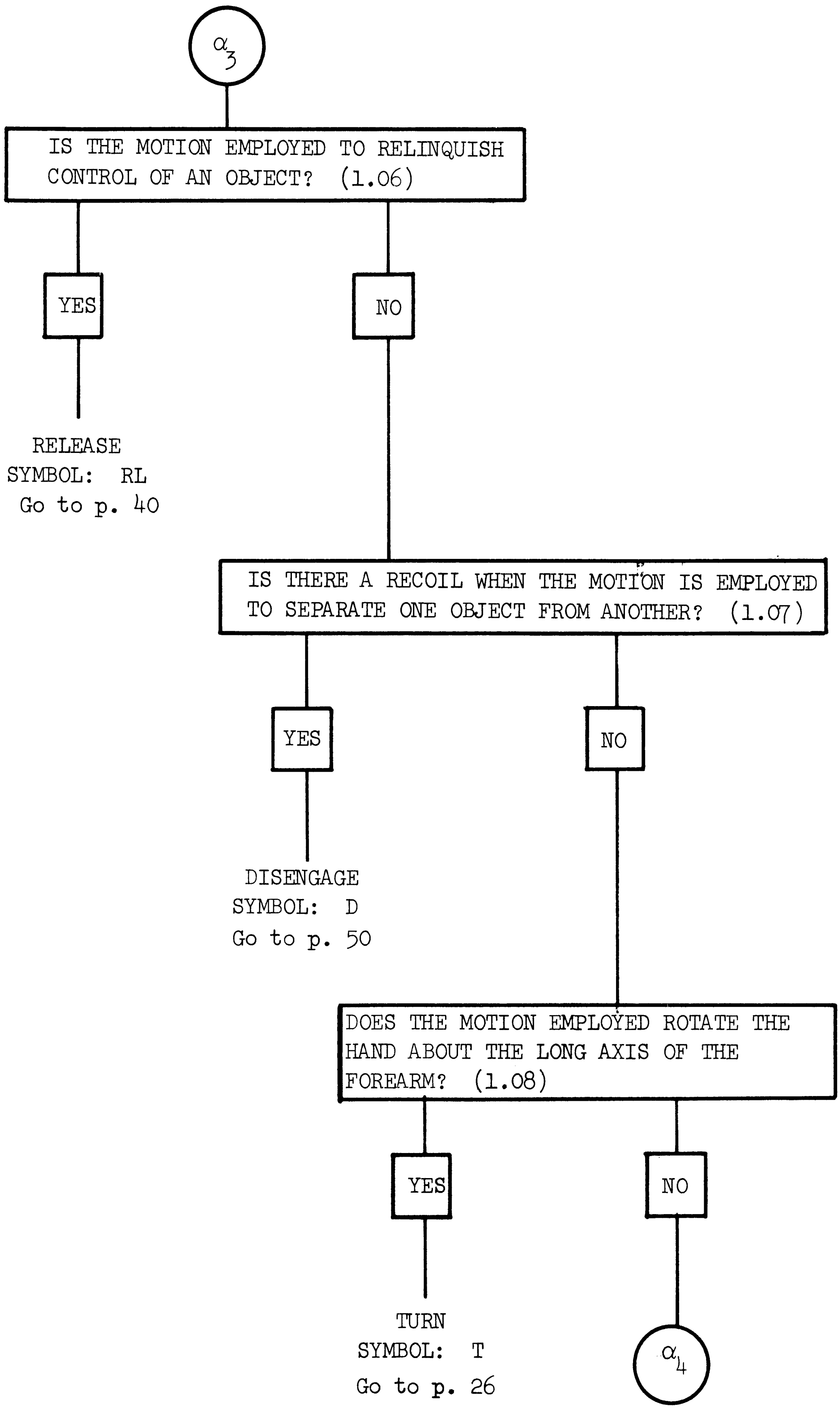


Fig. 1. (Continued).

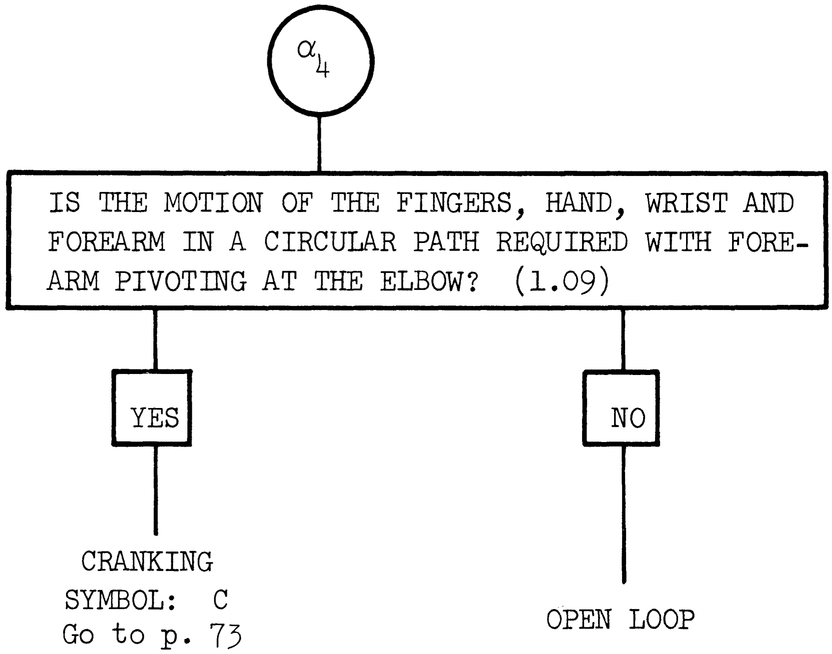


Fig. 1. (Concluded).

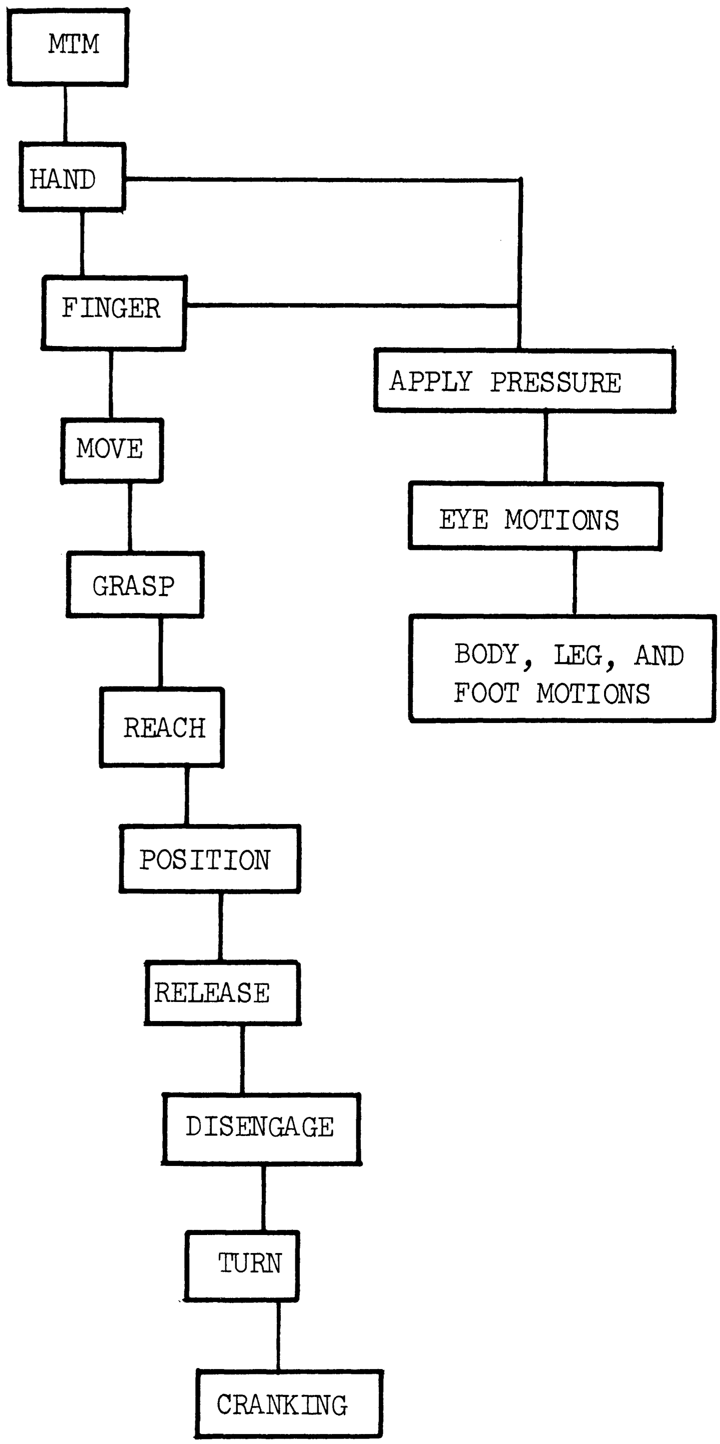


Fig. 2. A schematic representation of a decision sequence for classifying MTM motions according to Åberg industry B.

CHAPTER 3

REACH

DEFINITION: "Reach is the basic hand or finger motion employed when the predominant purpose is to move the hand or fingers to a destination.

1. Reach is performed only by the fingers or hand. Moving the foot to a trip lever would not be classified as a reach.
2. The hand may be carrying an object and still classified as a reach provided the predominant purpose is only to move the hand or fingers and not the object. An example would be 'reach' for an eraser while still holding chalk in the same hand.
3. Short reaches can be performed by moving only the fingers; longer reaches involve motion of the hand, forearm, and upper arm." (1.04)

Complete specification of the motion "reach" consists of the following steps:

i) Determine "Case," e.g., A, B, etc. (Fig. 3)

ii) Determine "Type," e.g., I, II, etc. (Fig. 4)

iii) Determine "Net distance," in in. (Fig. 5)

iv) Assign "Time Value" in TMU (Fig. 6)

Procedure: After determining from the main tree that the motion under consideration is "reach," follow through the decision models as listed above in sequence and obtain the complete specification of "reach" with the corresponding time value.

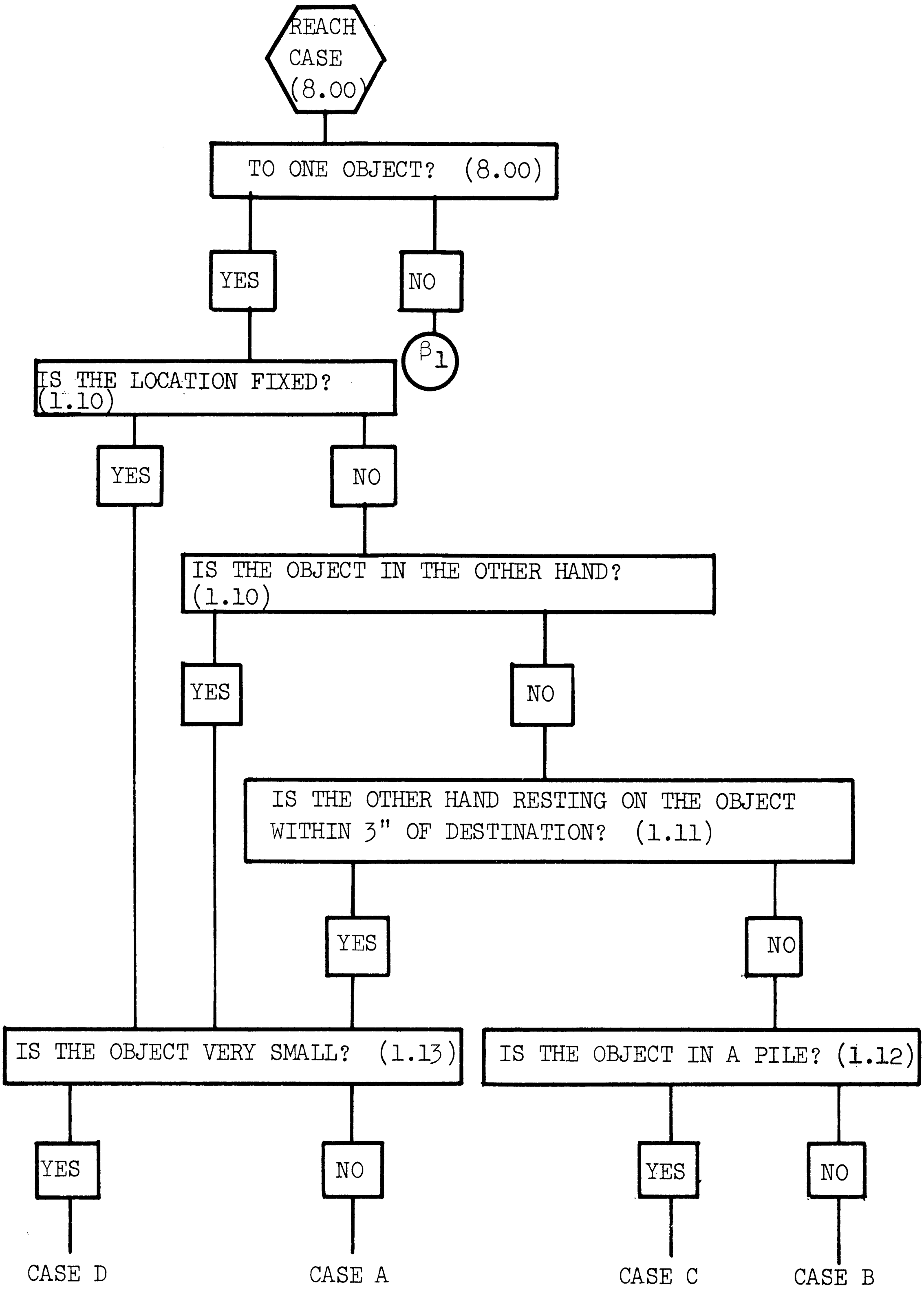


Fig. 3. Reach—case.

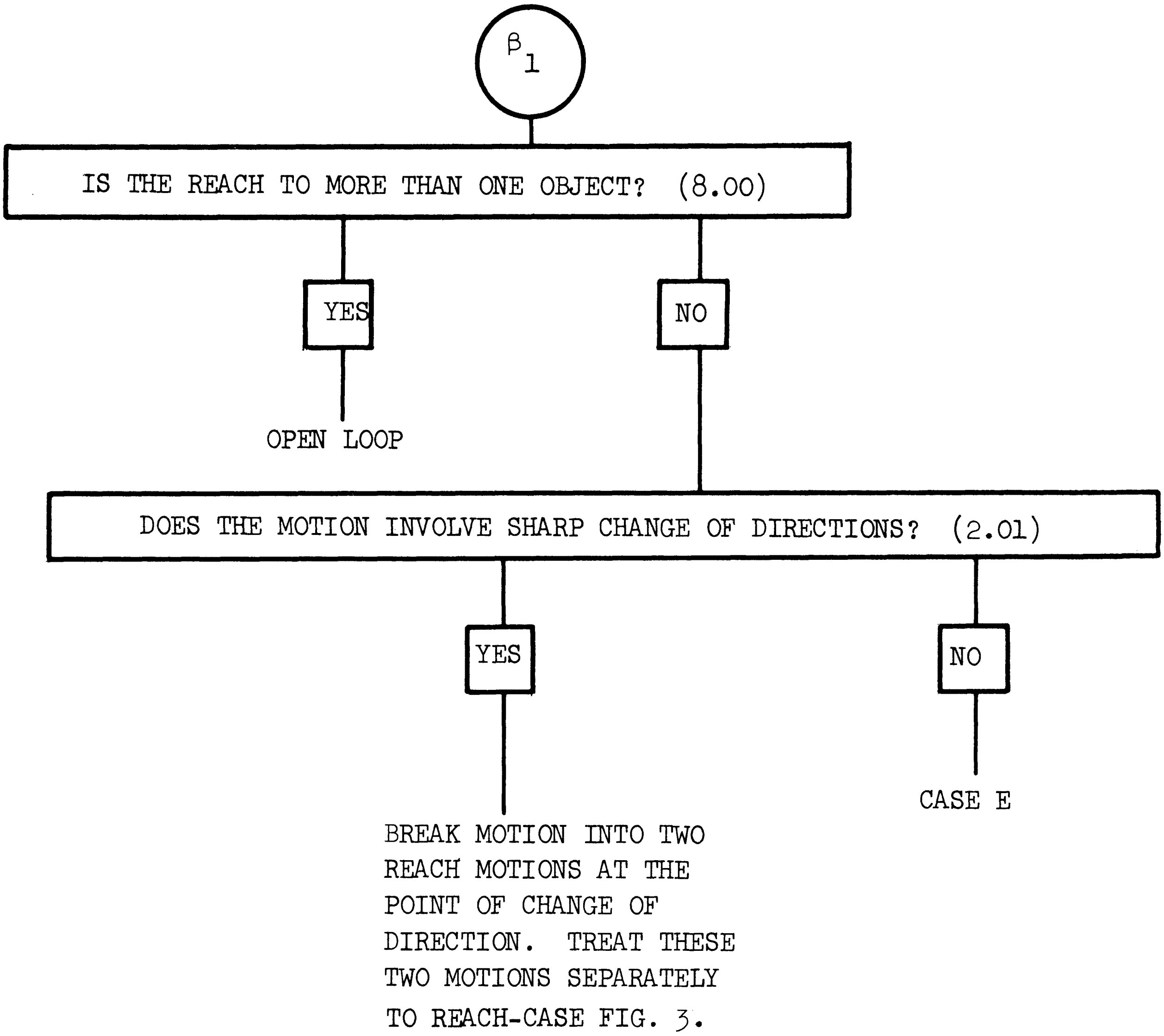
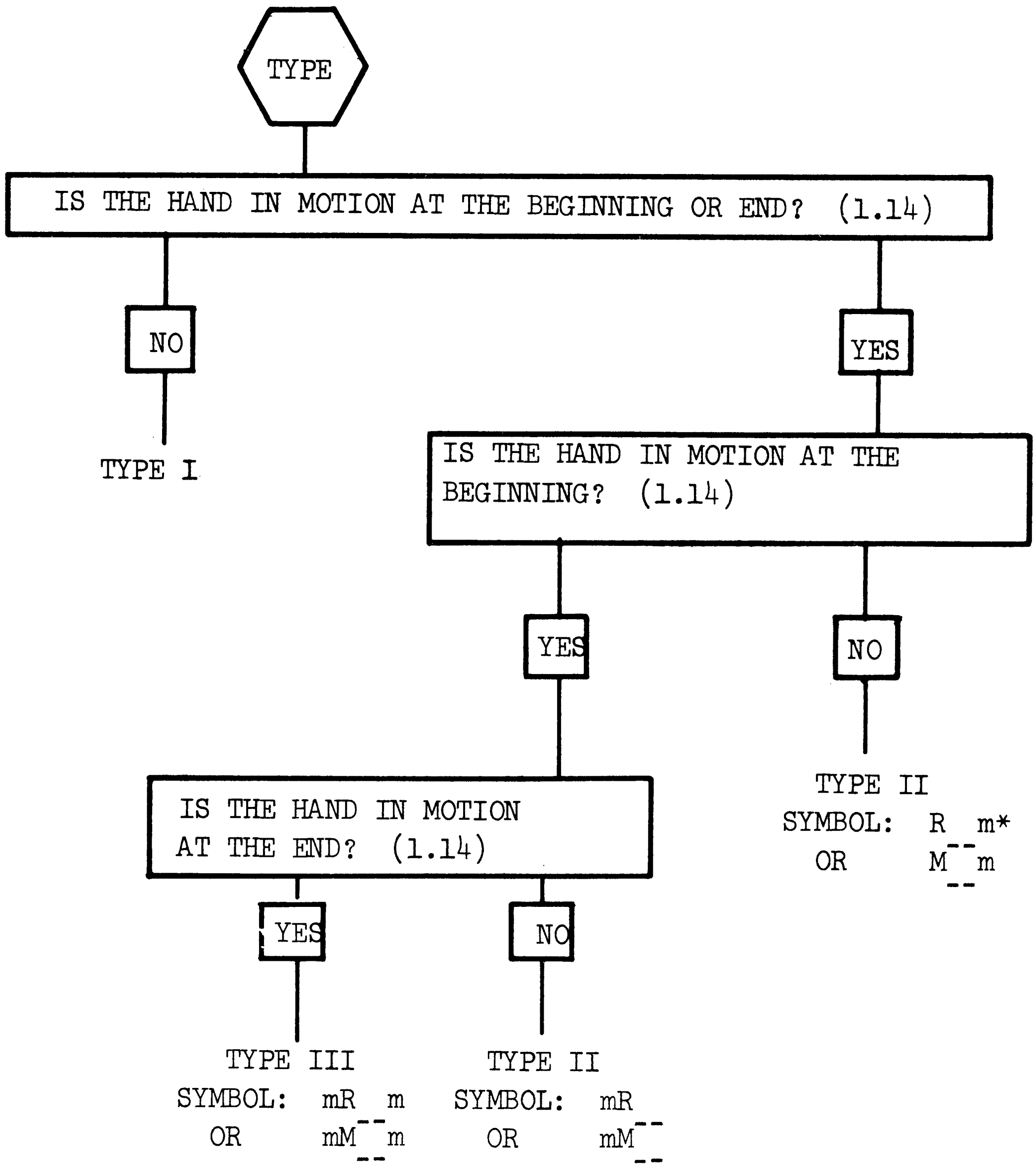


Fig. 3. (Concluded).



*The first spacing (-) is for the net distance travelled and the second spacing for the motion case.

Fig. 4. Reach--type of motion.

Net distance (ND) refers to the arc distance travelled by the knuckle of the index finger from the beginning to the end of the motion without any finger, wrist, or body assistance.

Let L = arc distance travelled by the index knuckle

Lss = length of <u>shoulder</u> travel during <u>simple</u> body assistance

Lsr = length of <u>shoulder</u> travel during <u>radial</u> body assistance

Lks = length of index <u>knuckle</u> travel due to <u>rotary</u> wrist assistance

Lkr = length of index <u>knuckle</u> travel due to <u>rotary</u> wrist assistance (as occurs in Reach-Turn or Move-Turn combined motions)

Lff = length of <u>finger</u> <u>tip</u> travel during <u>finger</u> assistance

Fig. 5. Reach—net distance.

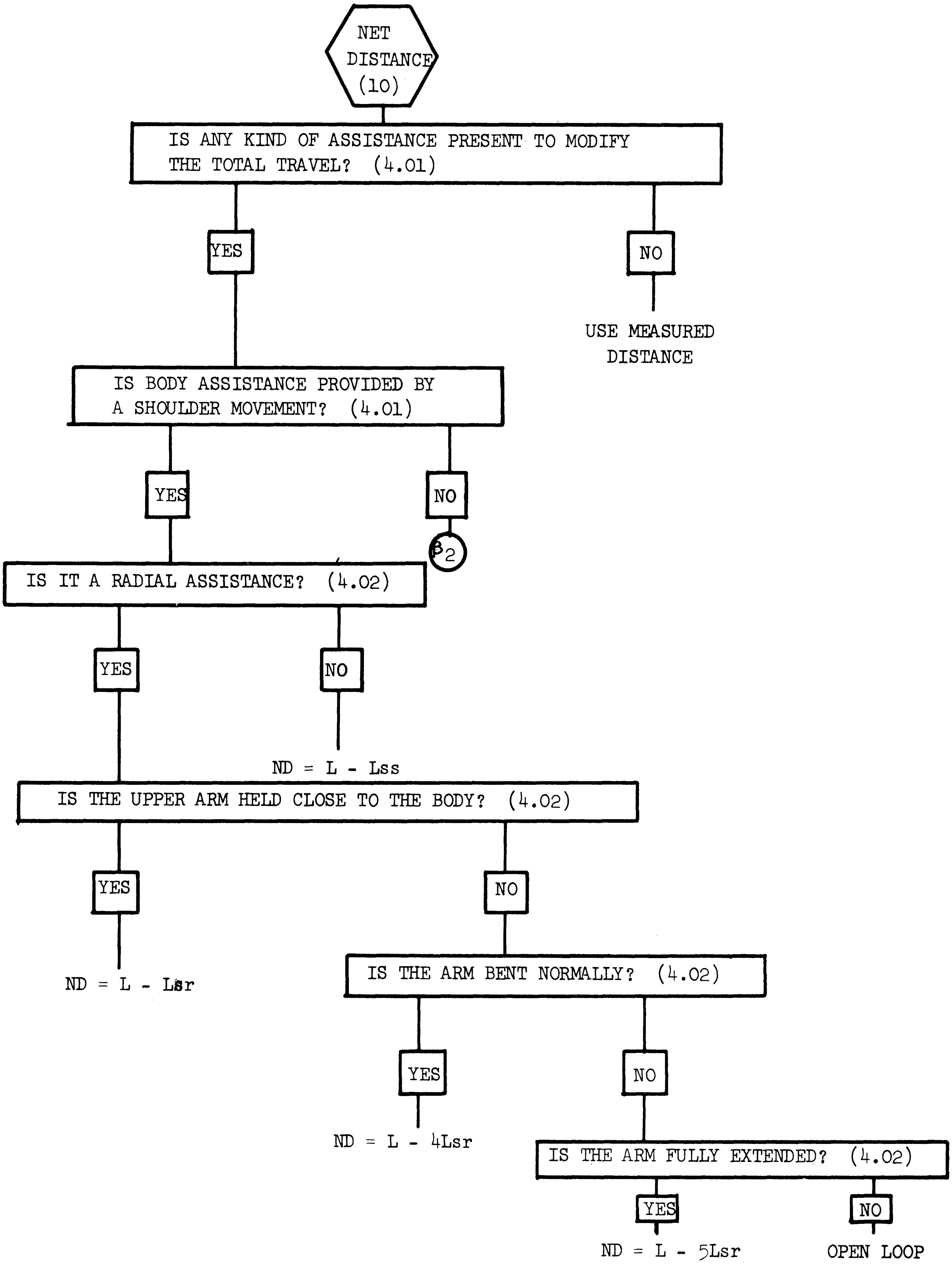


Fig. 5. (Continued).

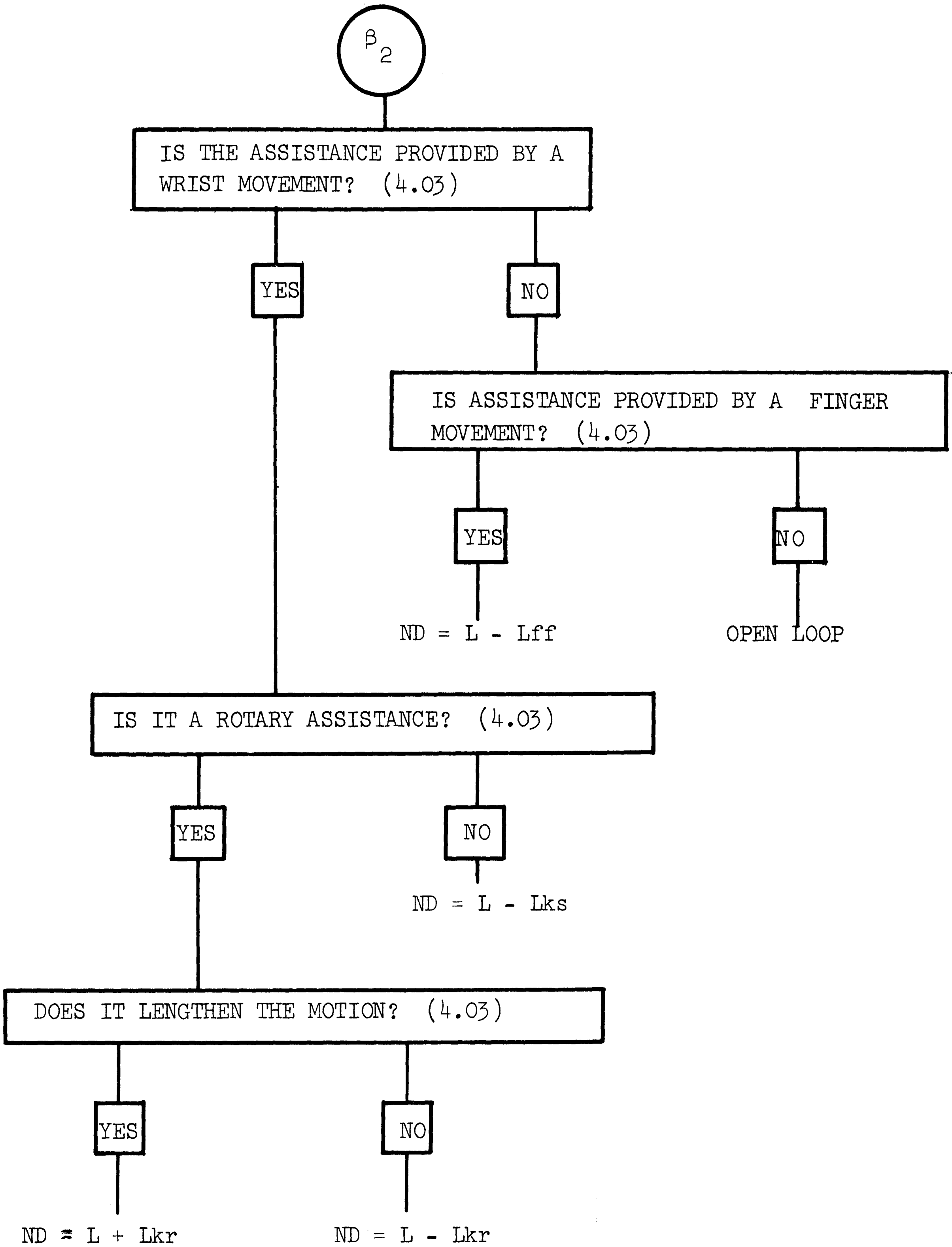
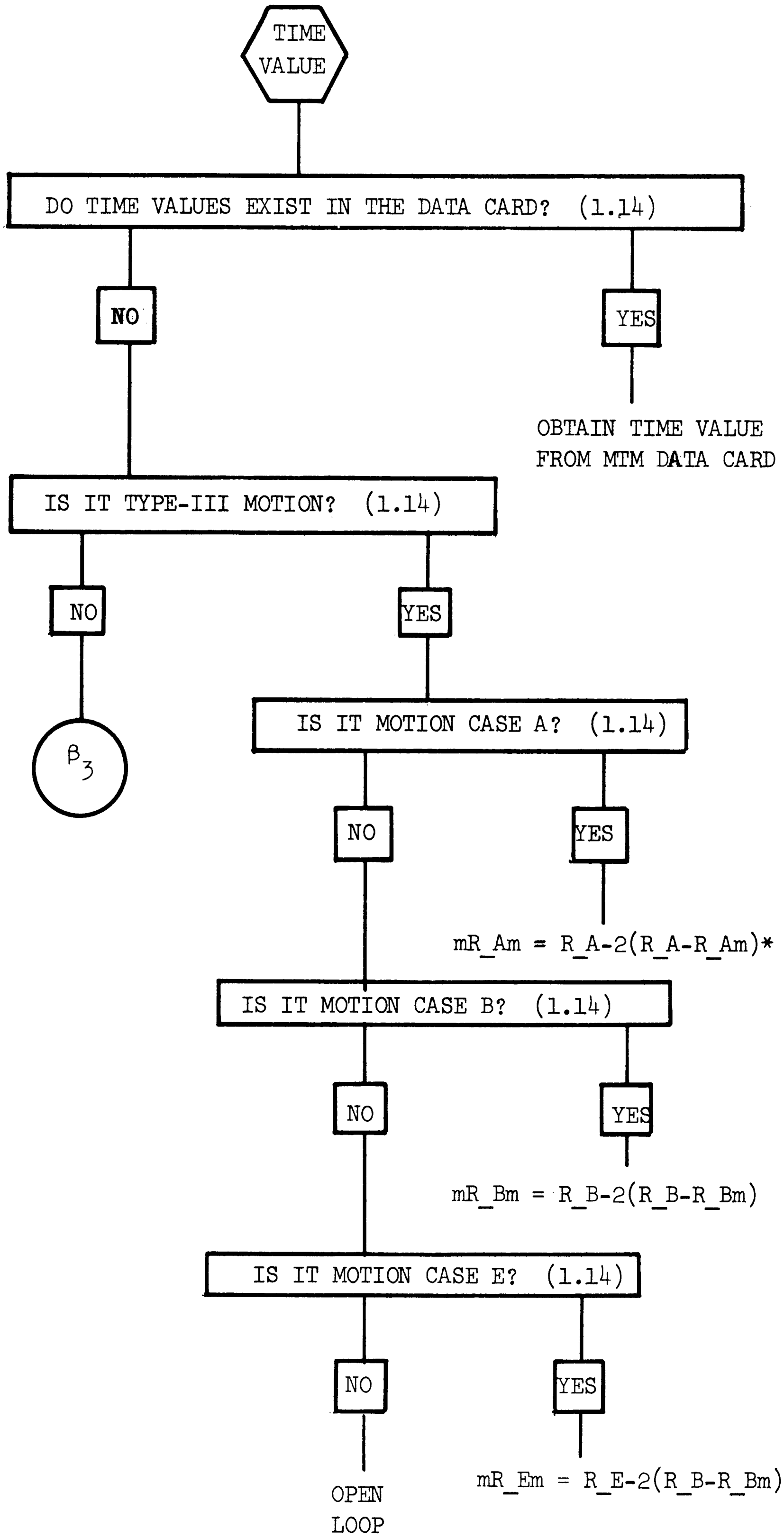


Fig. 5. (Concluded).



*Time values for all the terms on the right-hand side of all the equations can be obtained from the MTM data card.

Fig. 6. Reach—time value.

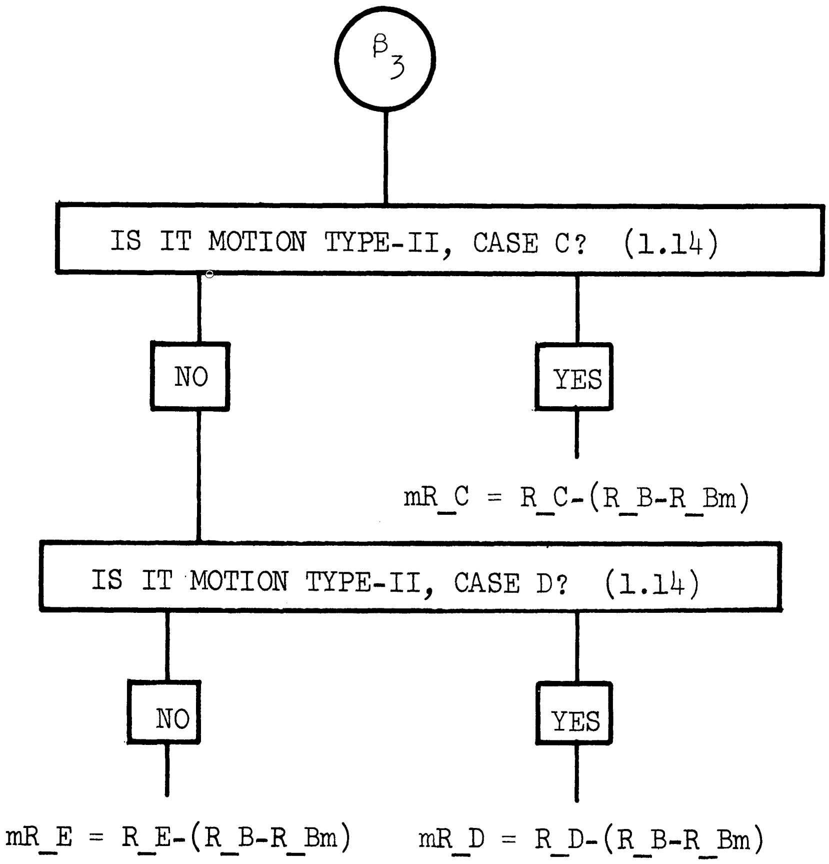


Fig. 6. (Concluded).

CHAPTER 4

MOVE

DEFINITION: "Move is the basic hand or finger motion employed when the predominant purpose is to transport an object to a destination.

1. Move is performed only by the fingers or hand. Pushing an object with the foot would not be classified as a move.
2. The hand must exert control over the object during the motion. In tossing an object aside, for example, the move motion ends when the fingers or hand release the object.
3. The fingers or hand may be pushing the object or sliding it; it is not necessary to carry the object.
4. Using the hand as a tool is classified as a move. The fingers or hand itself would be considered as a tool being carried by itself." (1.01)

Complete specification of the motion "move" consists of the following steps:

i) Determine "Case," e.g., A, B, etc. (Fig. 7)

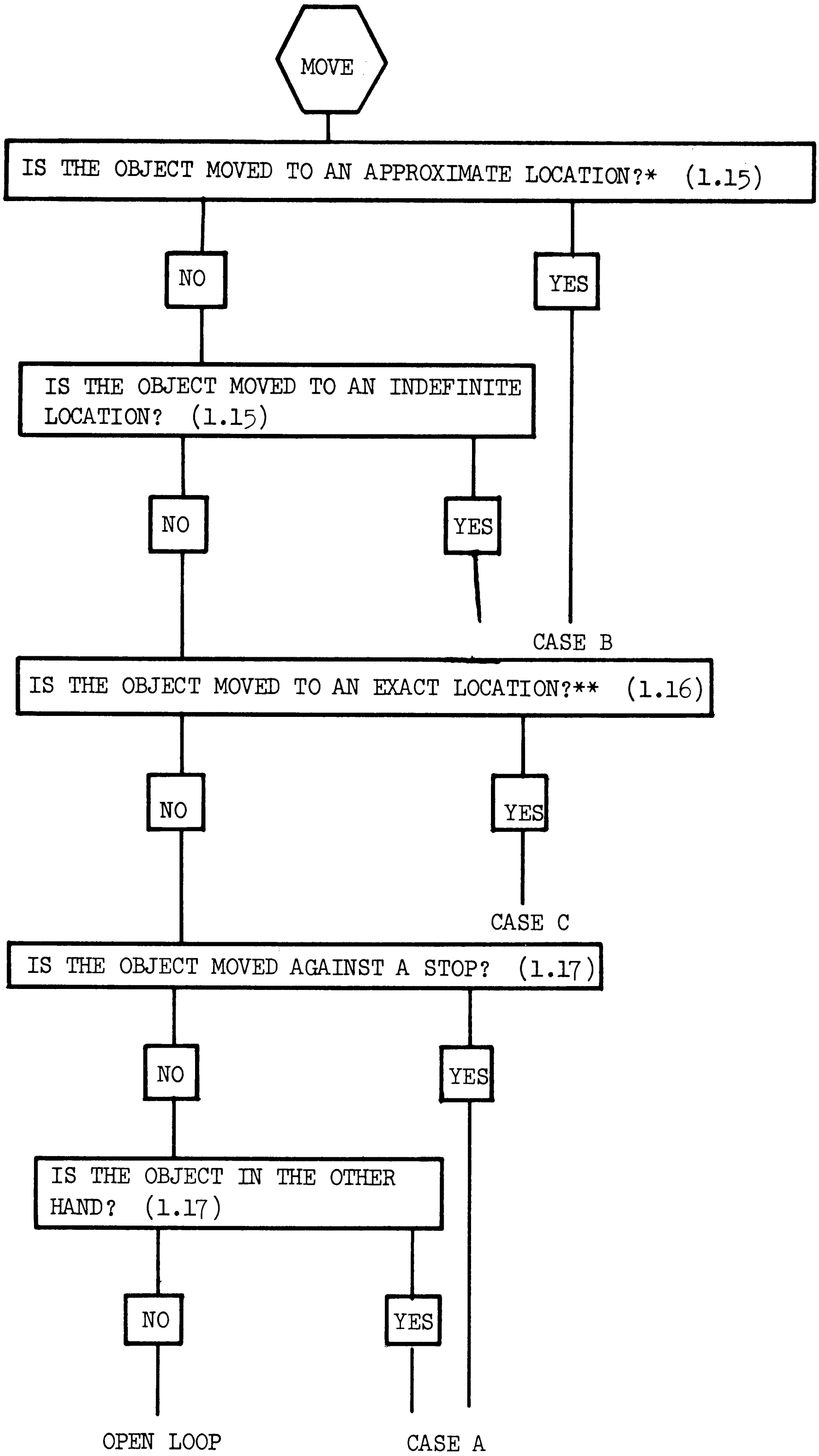
ii) Determine "Type," e.g., I, II, etc. (Fig. 4)

iii) Determine "Net distance," in in. (Fig. 5)

iv) Assign "Time Value" in TMU (Fig. 8)

v) Apply correction for "Weight-factor" (Fig. 9)

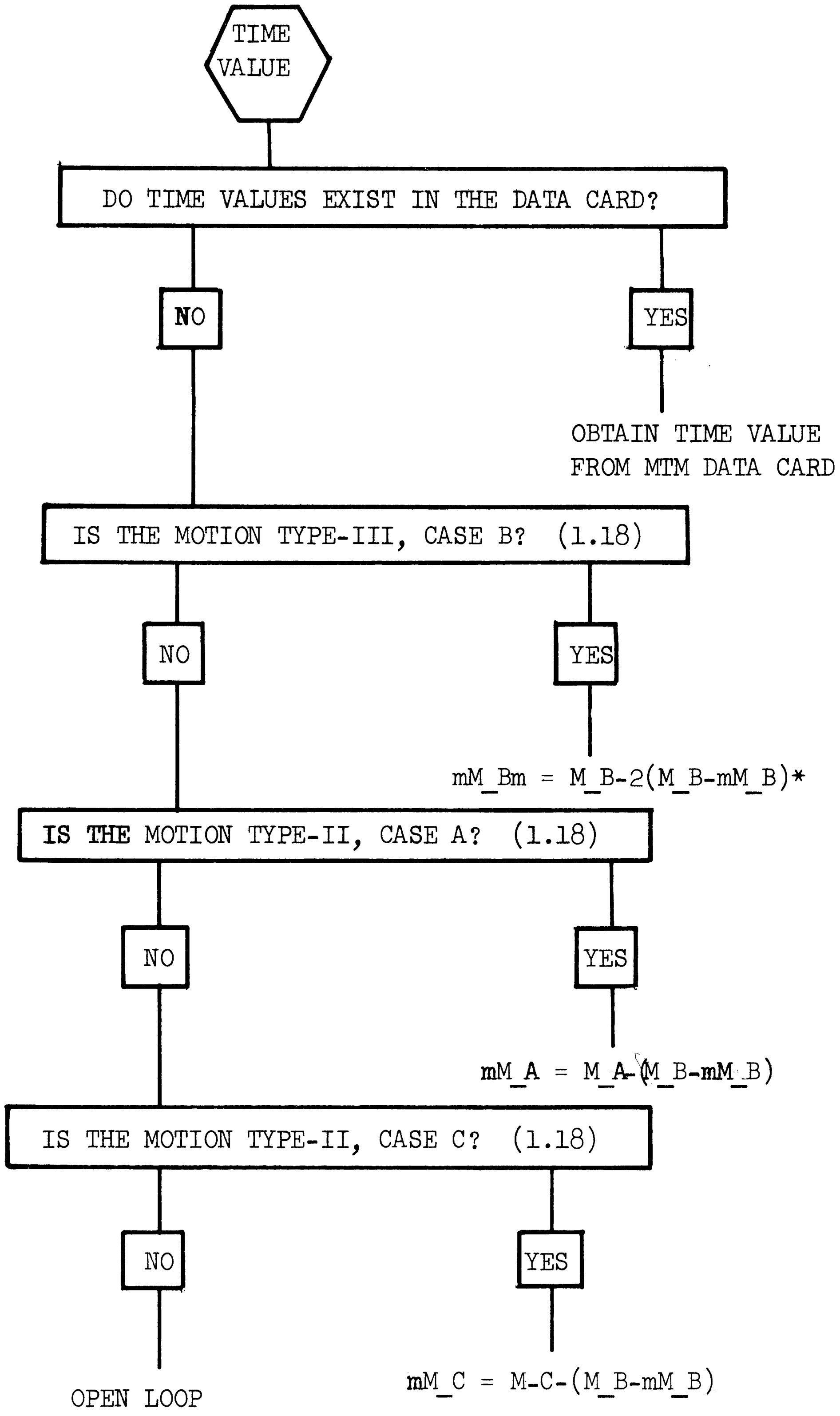
Procedure: After determining from the main tree that the motion under consideration is "move," follow through the decision models as listed above in sequence and obtain the complete specification of "move" with the corresponding time value.



*Approximate location implies that the location of the object is within an inch or two of a central point.

**Exact location implies that the hand will transport the object within 1/2 in. of a central point.

Fig. 7. Move—case.



*Time values for all the terms on the right-hand side of all the equations can be obtained from the MTM data card.

Fig. 8. Move—time value.

The following terminology is used in this decision model:

w = total weight of the object(s), lb.

= net weight of the object(s) <u>per</u> <u>hand</u>, lb.

fc = average coefficient of friction

= 0.4 for wood and wood

= 0.4 for wood and metal

= 0.3 for metal and metal contacts

E.N.W. = Effective Net Weight = (N.W.) x (fc)

D.C. = Dynamic Component of the weight factor. The MTM data card gives the values of this for different E.N.W.

S.C. = Static Component of the weight factor. The MTM data card gives the different values of this for different E.N.W.

C.V. = Time value from MTM data card before applying correction for weight

Fig. 9. Move—weight factor. (1.19)

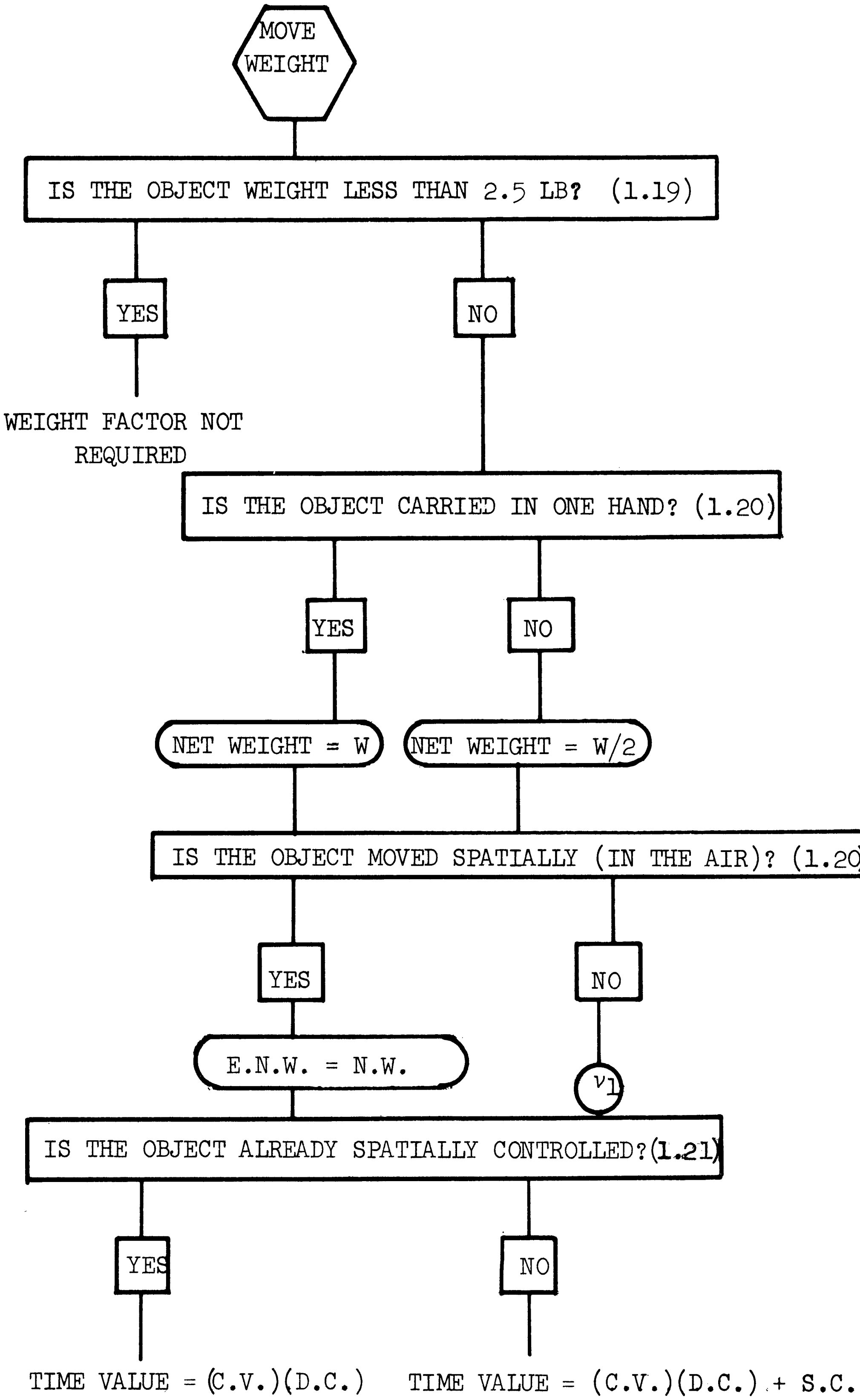


Fig. 9. (Continued).

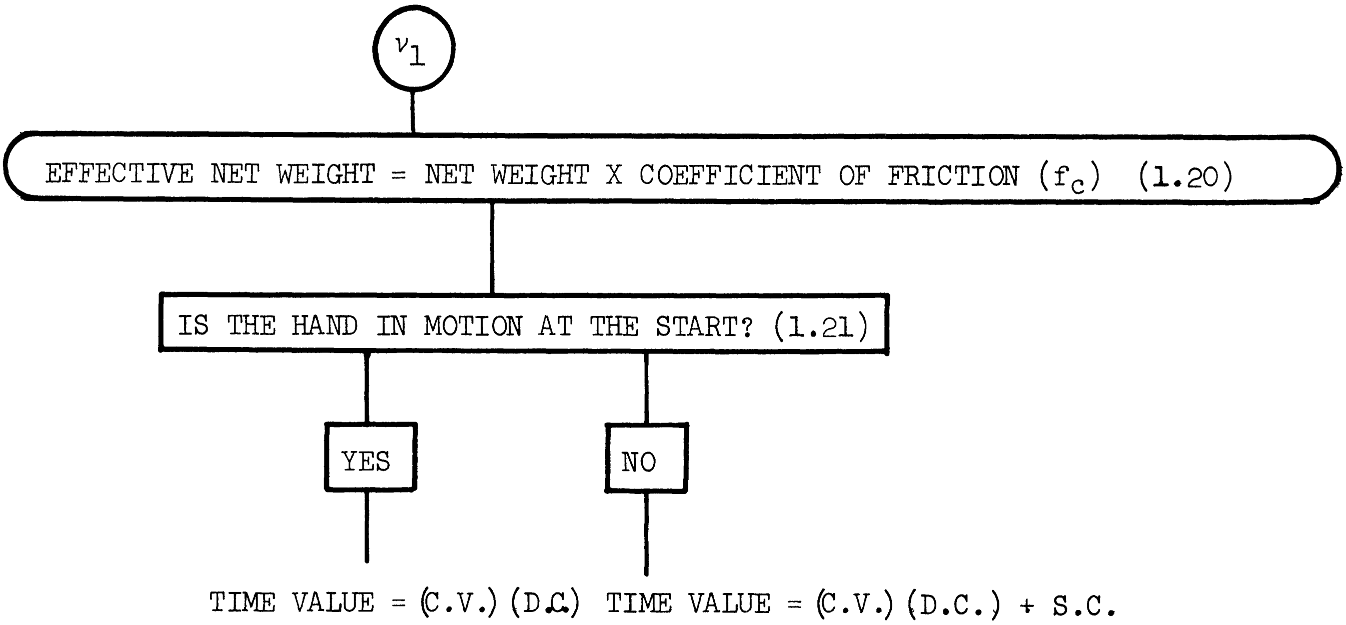


Fig. 9. (Concluded).

CHAPTER 5

TURN

DEFINITION: "Turn is the basic motion employed to rotate the hand about the long axis of the forearm.

1. The hand may be empty or holding an object.
2. Turn cannot be made holding the wrist firm. Turn involves the two bones in the forearm and pivoting motion at the elbow." (1.08)

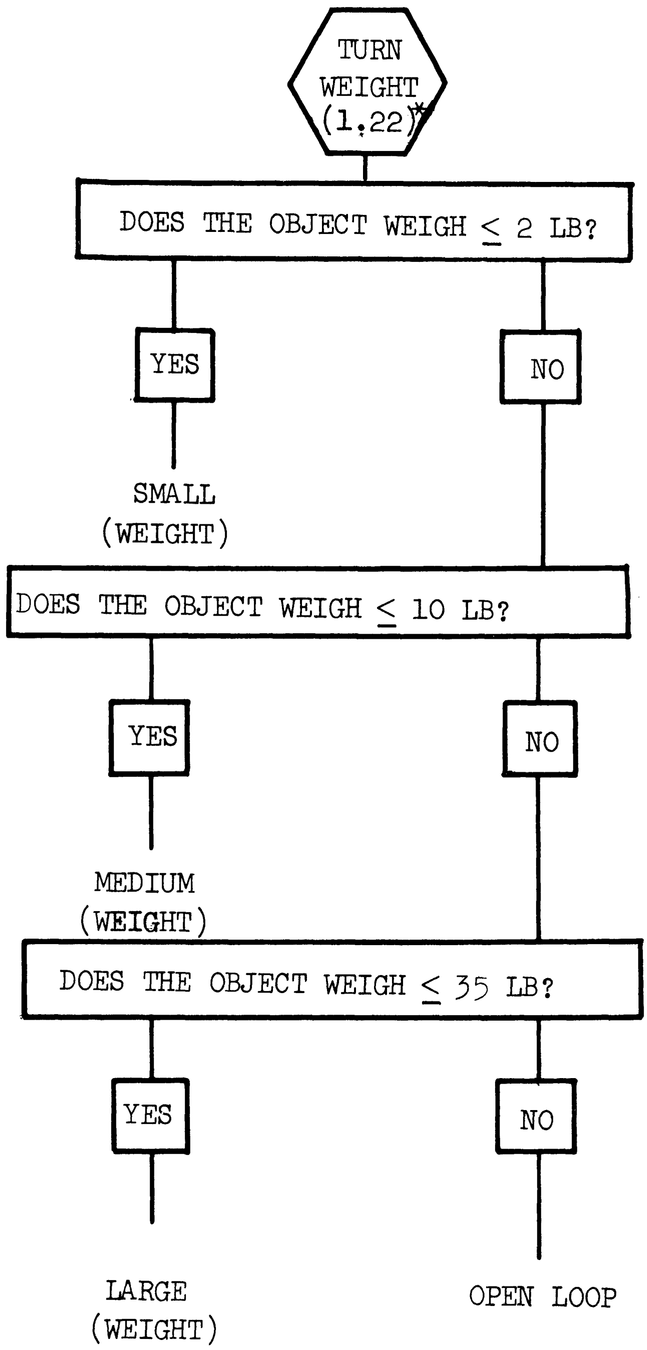
Complete specification of the motion "turn" consists of the following two steps:

i) Determine the "Weight Category," e.g., small, medium, etc. (Fig. 10)

ii) Determine "Degrees" turned (Fig. 11)

iii) Assign "Time Value" in TMU from MTM data card

Procedure: After determining from the main tree that the motion under consideration is "turn," follow through the decision models as listed above in sequence and obtain the complete specifications of "turn" with the corresponding time value.



*This reference applies to all the decisions in this model.

Fig. 10. Turn—weight.

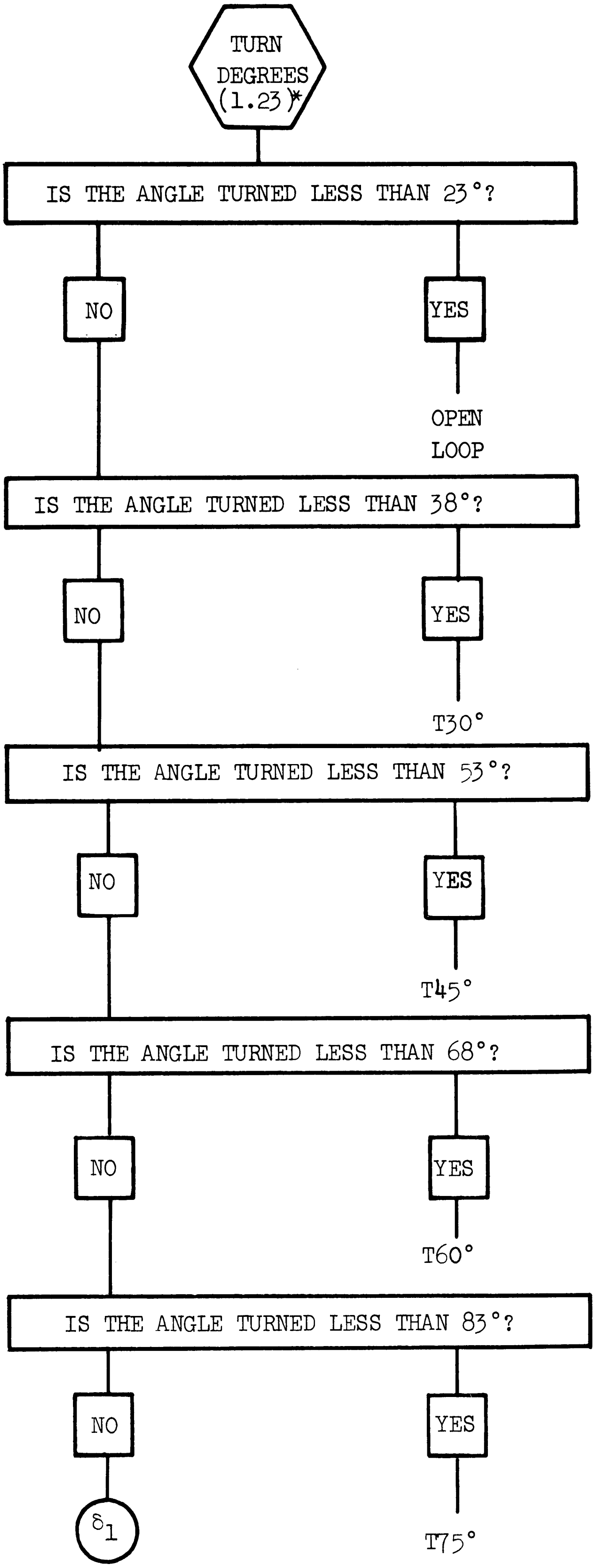


Fig. 11. Turn--degrees.

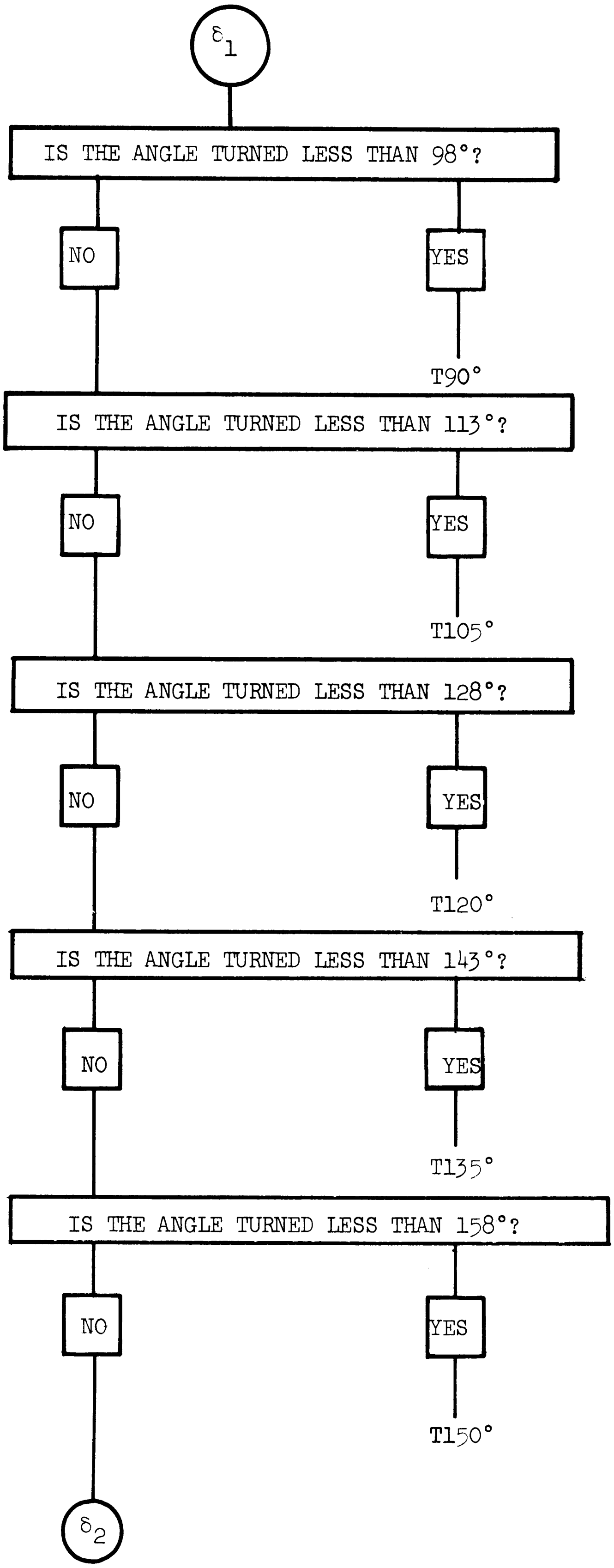


Fig. 11. (Continued).

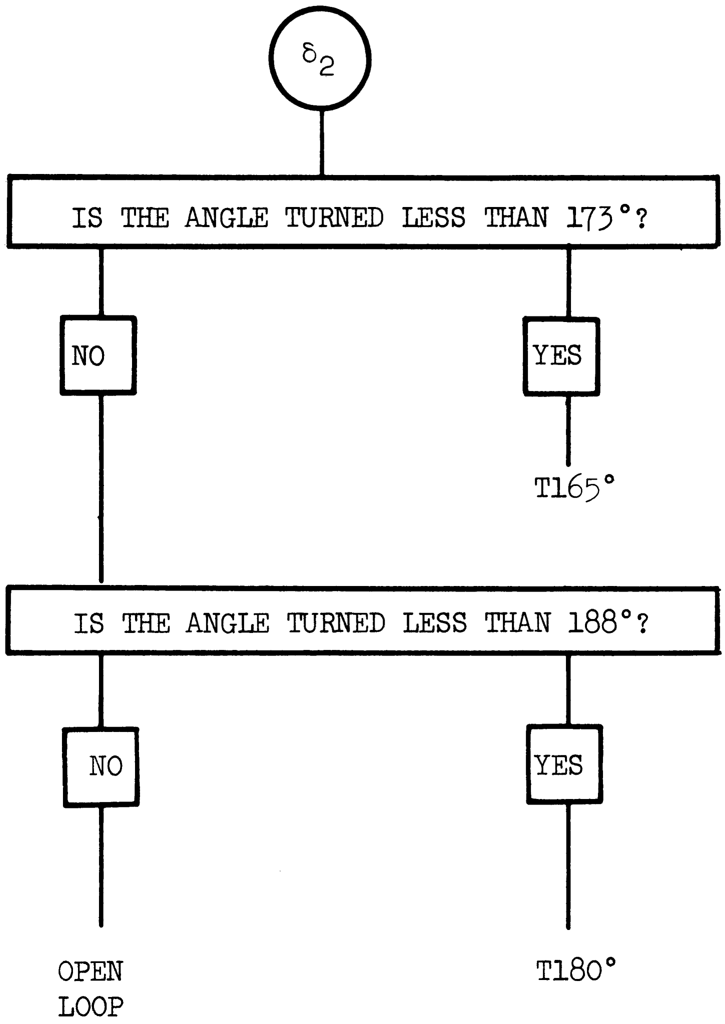


Fig. 11. (Concluded).

CHAPTER 6

APPLY PRESSURE

DEFINITION: "Apply pressure" is an application of muscular force to overcome object resistance, accompanied by little or no motion.

1. Apply pressure is a hesitation or lack of motion.
2. The force required for apply pressure is greater than that required for a normal move or turn against resistance.
3. Apply pressure frequently is indicated by a setting of the muscles.
4. Apply pressure may be performed by any body member.

"Apply pressure" can be specified by any one of the following two methods:

Method I - Table III of the MTM data card.

Complete specification of the "apply pressure" by this method consists of the following steps:

i) Determine category, e.g., AP1 or AP2 (Fig. 12)

ii) Assign "Time Value" in TMU from MTM data card

Procedure: After determining from the main tree that the motion under consideration is "apply pressure," follow through the decision model listed above and obtain the complete specifications of "apply pressure" with the corresponding time value.

Method II - Table 2, (supplementary data) of MTM data card.

Complete specification of "apply pressure" by this method consists of the following steps:

i) Determine period of "Apply Force" - AF

ii) Determine period of "Dwell Minimum" - DM

iii) Determine period of "Release Force" - RLF

iv) Compute TMU for "Apply Pressure" - AP, by the relation AP = AF + DM + RLF

v) Add TMU for number of "regrasps" - G2, if occurs, and compute TMU for "Complete Apply Pressure" - APB, by the relation APB = AP + G2

Procedure: After determining from the main tree that the motion under consideration is "apply pressure," follow through the decision model (Fig. 13) and obtain the complete specification of "apply pressure" with the corresponding time value.

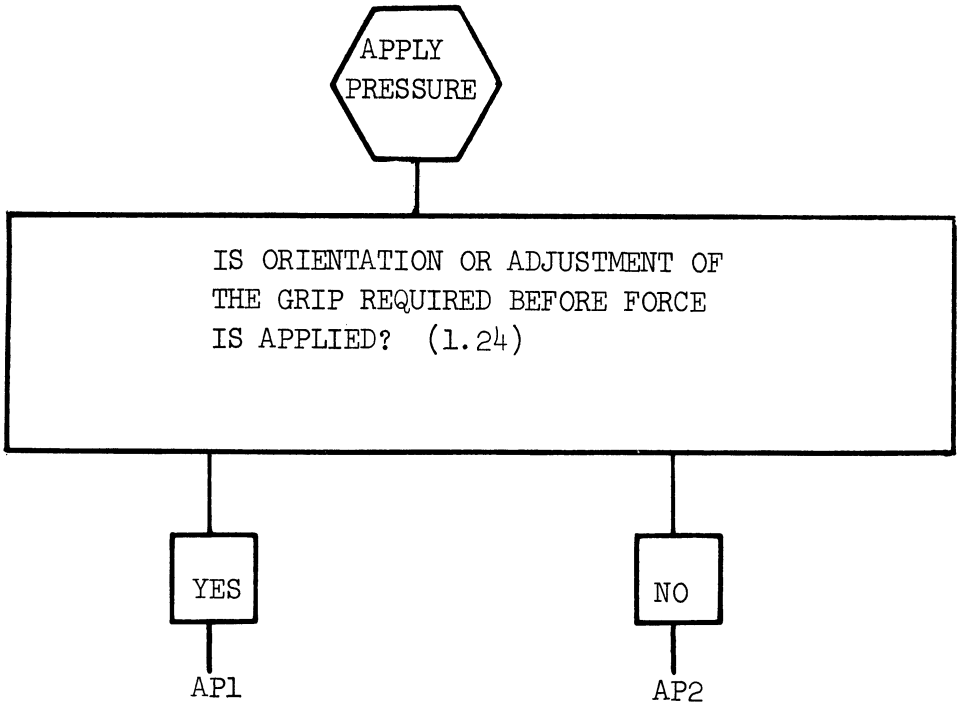
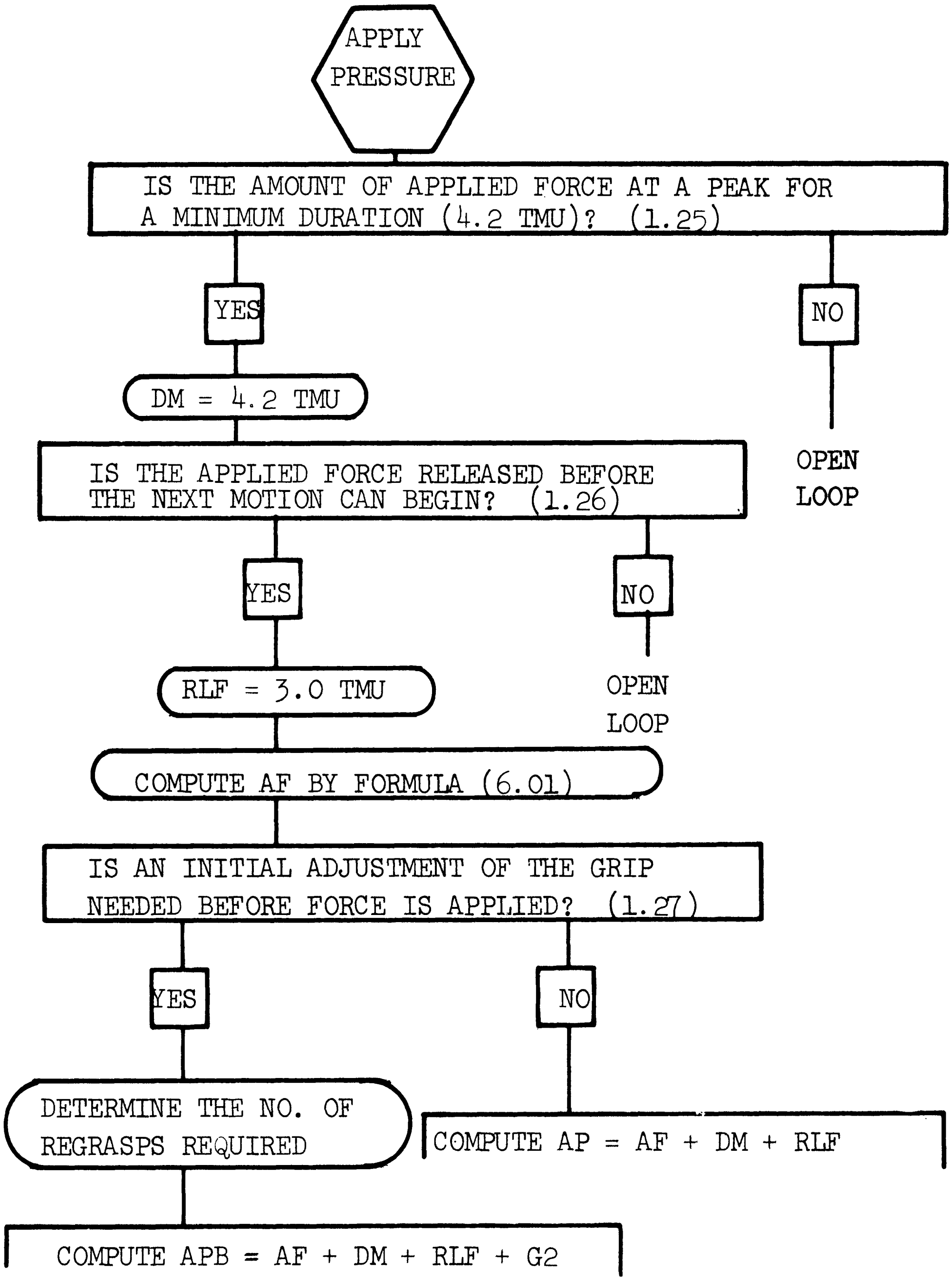


Fig. 12. Apply pressure.



FORMULA (6.01)

APPLY FORCE (AF) = 1.0 + (0.3 x lb) TMU for up to 10 lb
= 4.0 TMU max for 10 lb and over

Fig. 13. Apply pressure—supplementary data.

CHAPTER 7

GRASP

DEFINITION: "Grasp is the basic finger or hand element employed to secure control of an object.

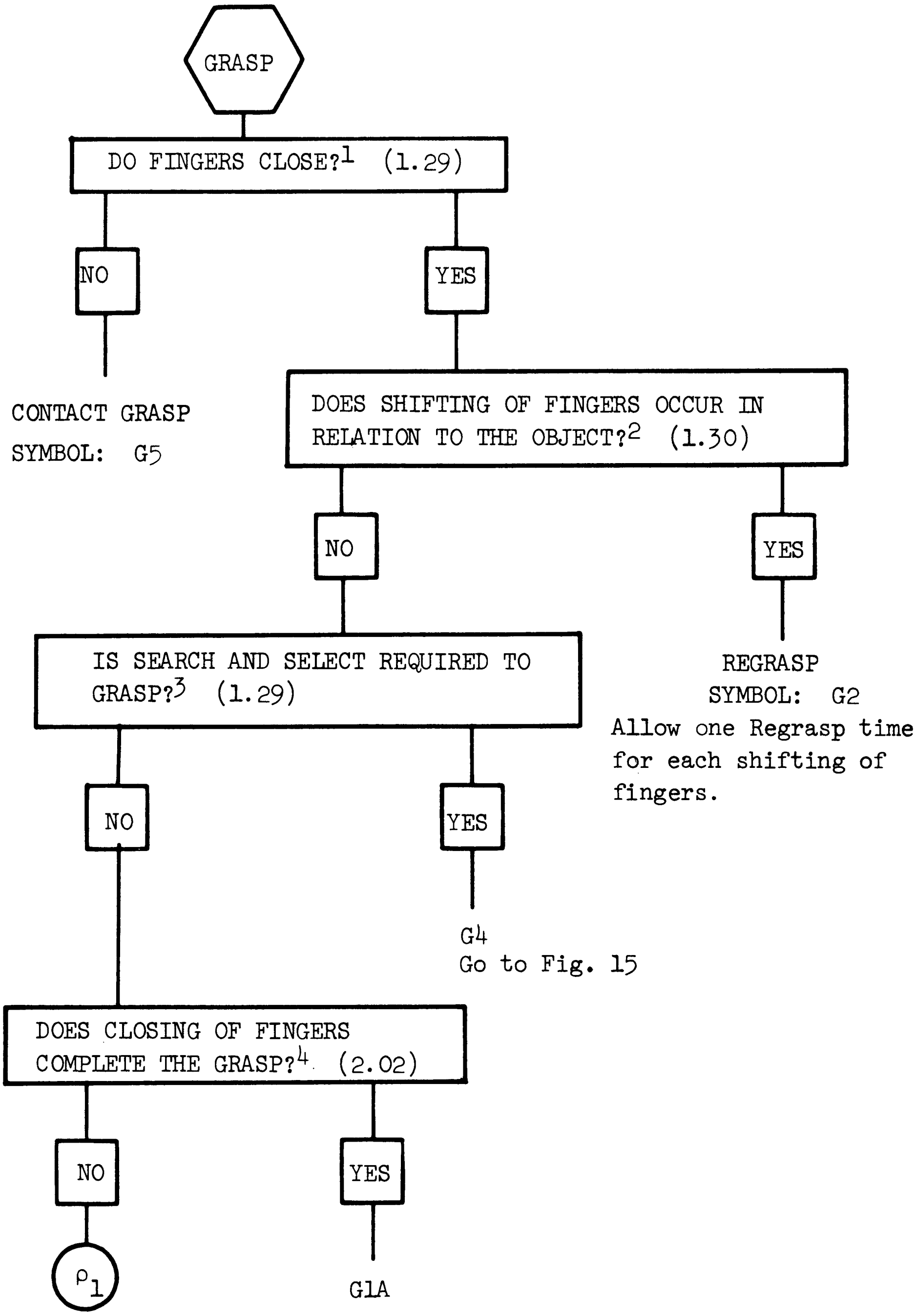
1. The hand or finger must obtain sufficient control of the object to be able to perform the next basic motion.
2. The object may be a single object or a group of stacked or piled objects which can be handled as though they were a single object." (1.02)

Complete specification of the motion "grasp" consists of the following two steps:

i) Determine "Case," e.g., G2, G3, etc. (Fig. 14)

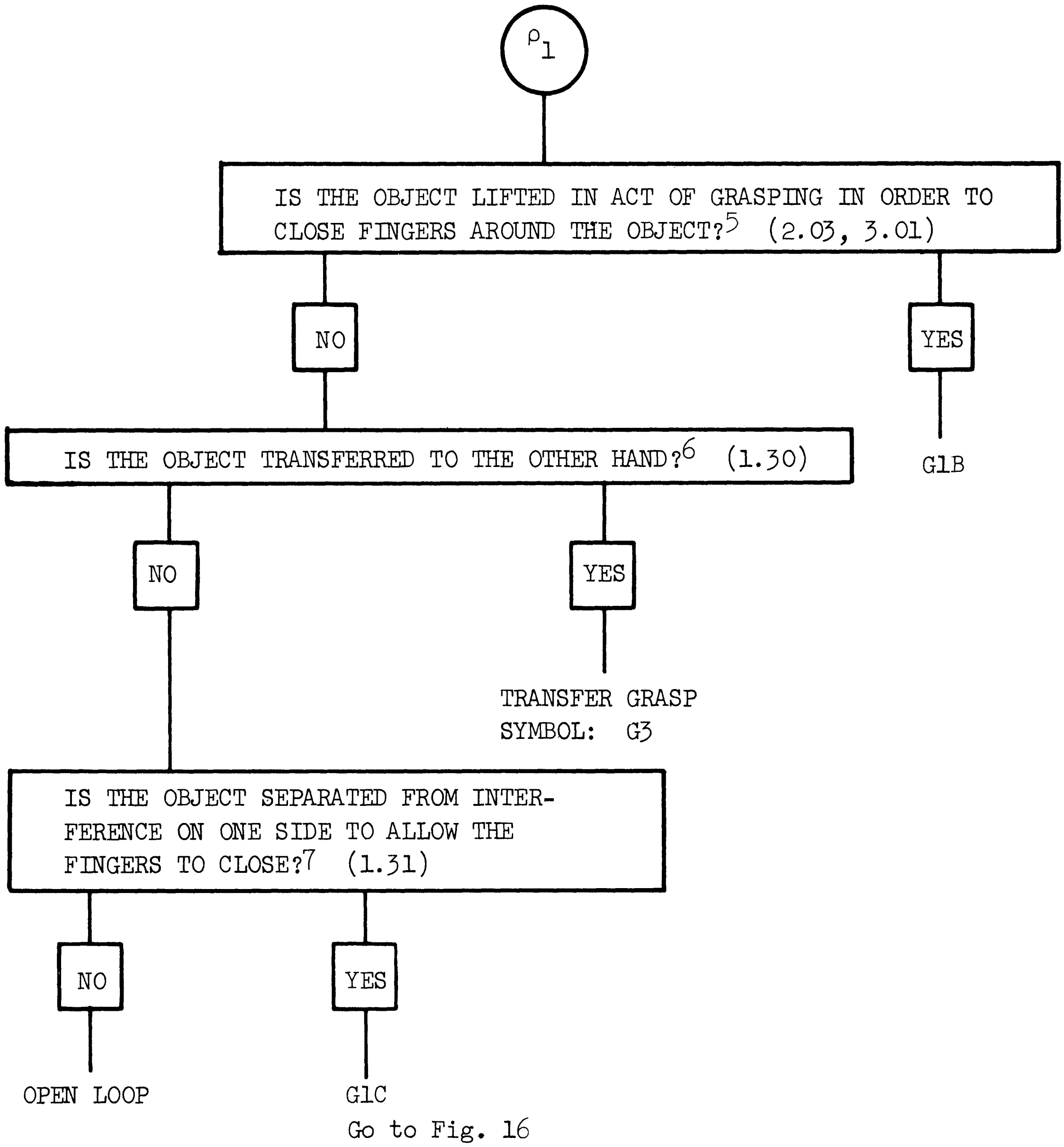
ii) Assign "Time Values" in TMU from MTM data card

<u>Procedure</u>: After determining from the main tree that the motion under consideration is "grasp," follow through the decision model listed above and obtain the complete specifications of "grasp" with the corresponding time value.



1. Contact grasp requires only contact of object with hand and/or fingers with-out closing of fingers around the object.
2. Regrasp consist of shifting the hold or relocating the fingers on an object already under control.
3. Search and select occúrs while grasping one amongst many, when simple closing of fingers may result in picking up more than one object.
4. A G1A grasp occurs when it is completed by the simple act of closing of fingers (small, medium, or large objects).

Fig. 14. Grasp—case.



5. G1B occurs when a very small object or object lying close against a flat surface must be lifted to permit closure of fingers.
6. Transfer grasp involves brief handling of the object by the fingers on both hands, which results in a hesitation before the other hand releases the object.
7. A G1C grasp is used where separation from interference on one side is required to allow closure of fingers.

Fig. 14. (Concluded).

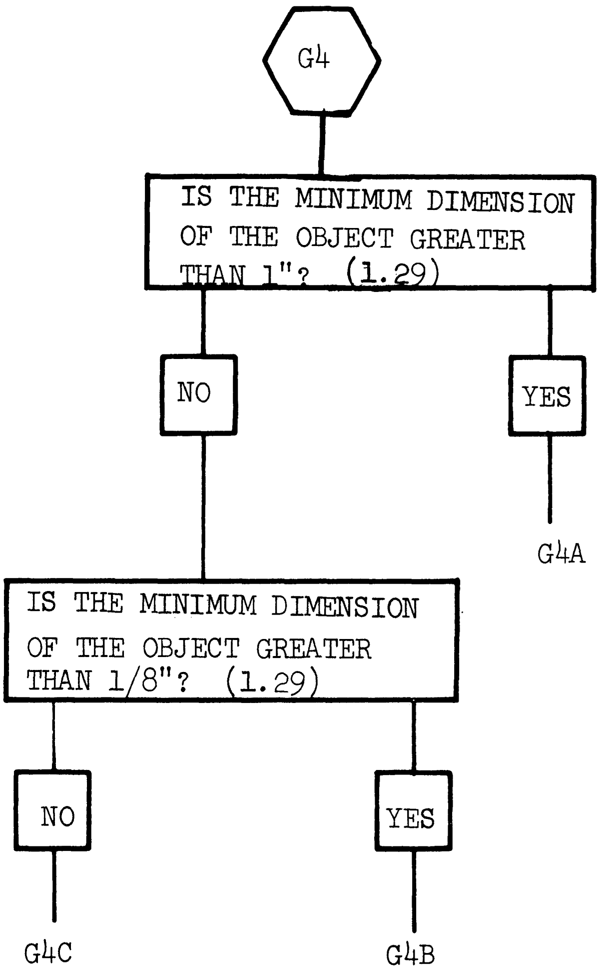
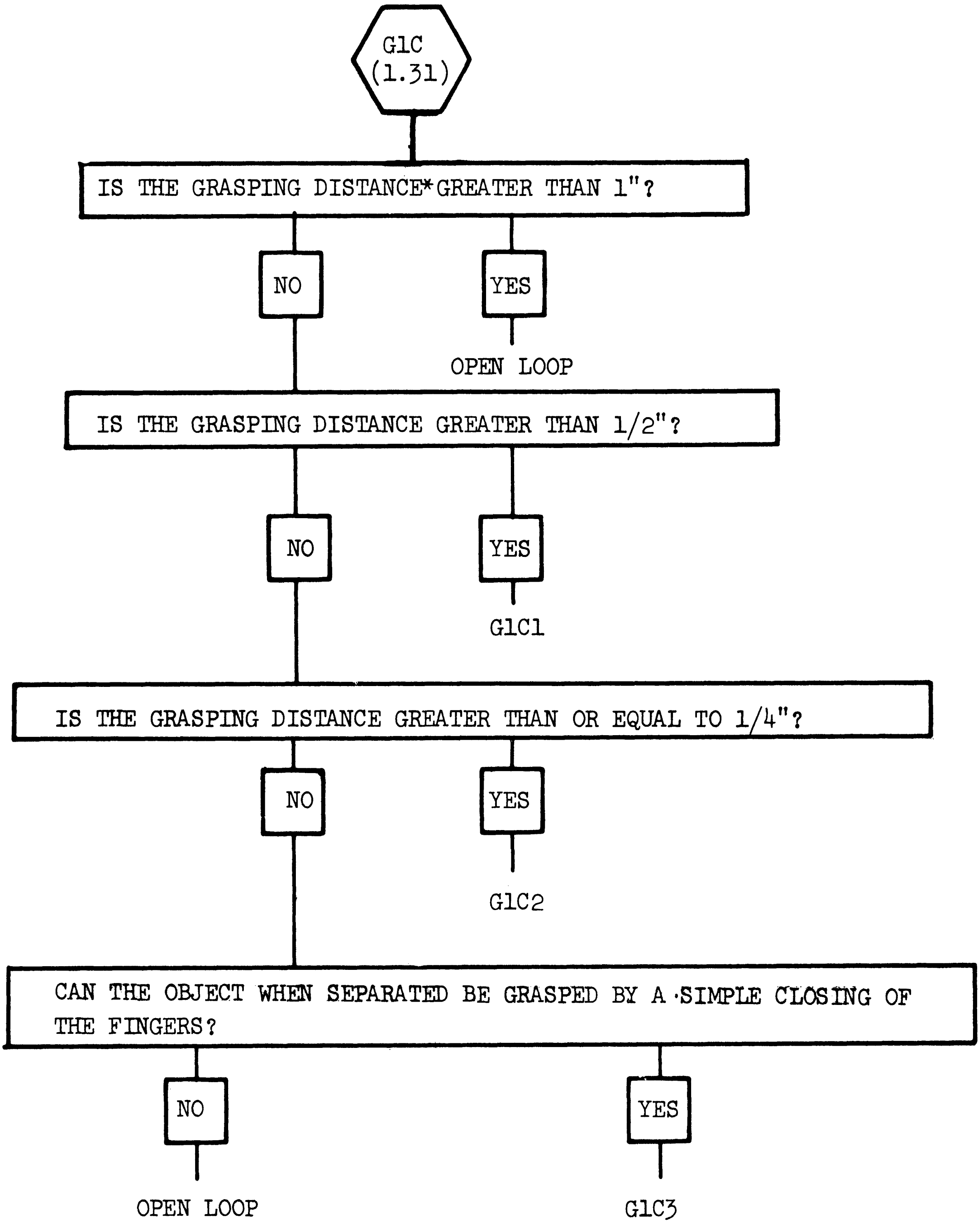


Fig. 15. Grasp—analysis of jumbled grasp (G4).



*Distance between the fingers (usually the thumb and the other fingers) when an object is grasped.

Fig. 16. Grasp--analysis of interference grasp (G1C).

CHAPTER 8

RELEASE

DEFINITION: "Release is the basic finger or hand motion employed to relinquish control of an object.

1. Release is performed only by the finger or the hand." (1.06)

Complete specification of the motion "release" consists of the following two steps:

i) Determine category, e.g., RL_1 or RL_2 (Fig. 17)

ii) Assign "Time Value" in TMU from MTM data card

Procedure: After determining from the main tree that the motion under consideration is "release," follow through the decision model listed above and obtain the complete specification of "release" with the corresponding time value.

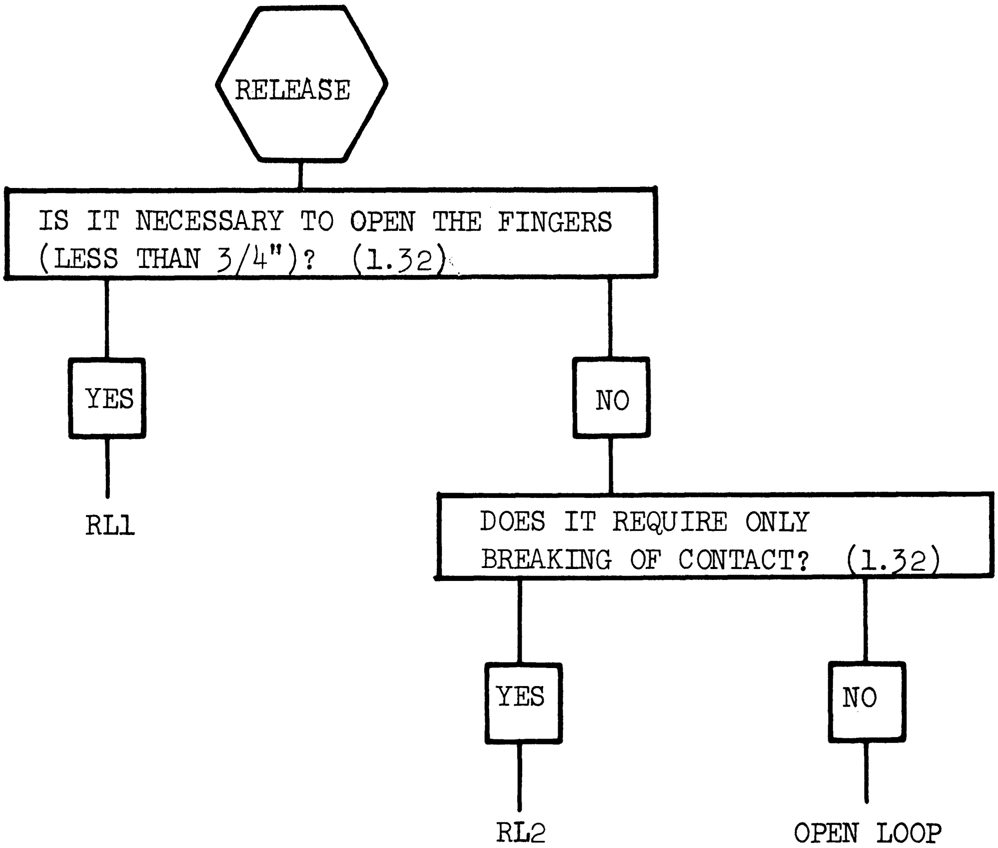


Fig. 17. Release.

CHAPTER 9

POSITION

DEFINITION: "Position is the basic finger or hand element employed to align, orient and engage one object with another to attain a specific relationship.

1. An accurate and predetermined relationship between the objects must be attained.
2. The relationship may be a nesting or mating of the objects, or may be a visual locating of one object to another.
3. Normally only objects can be positioned; occasionally the finger or hand may be used as a tool and considered as an object in positioning.
4. Align is to line up the two parts so that they have a common axis." (1.05)

"Position" can be specified by any one of the following two methods:

Method I - Table V of MTM data card.

Complete specification of "position" by this method consists of the following steps:

i) Determine "Class of Fit," e.g., P1, P2, etc.
   Model I (Fig. 18) and Model II (Fig. 19)

ii) Determine case of "Symmetry," e.g., Symmetrical (S), Nonsymmetrical (NS), etc. (Fig. 20)

iii) Determine "Ease of Handling," e.g., Easy to Handle (E), etc. (Fig. 21)

iv) Assign "Time Value" in TMU from MTM data card

<u>Procedure</u>: After determining from the main tree that the motion under consideration is "position," follow through the decision models as listed above in sequence and obtain the complete specifications of "position" with the corresponding time value.

<u>Method II</u> - Supplementary data, Table 1 of MTM data card.

Complete specification of the motion "position" by this method consists of the following steps:

i) Determine case of "Clearance," e.g., P21, P22, etc. (Fig. 22)

ii) Determine case of "Symmetry," e.g., Symmetrical (S), Nonsymmetrical (NS), etc. (Fig. 20)

iii) Determine "Depth of Insertion," e.g., P--1, P--2, etc. (Fig. 23)

iv) Assign "Time Value" in TMU from MTM data card

v) Add TMU for "Regrasp" and/or "Apply Pressure," if occurs to data card value

<u>Procedure</u>: After determining from the main tree that the motion under consideration is "position," follow through the decision models as listed above in sequence and obtain the complete specifications of "position" with the corresponding time value.

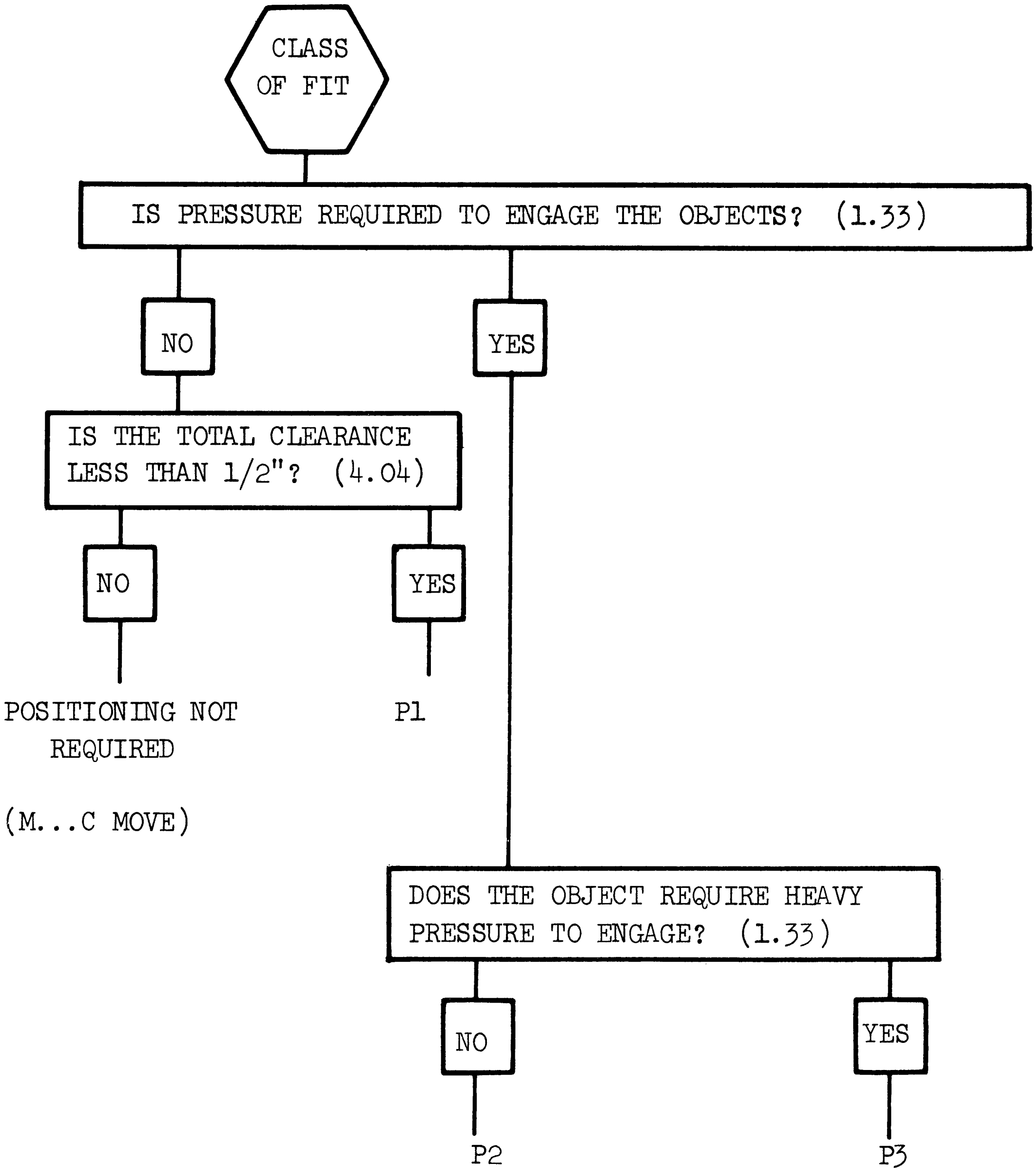


Fig. 18. Class of fit—Model I.

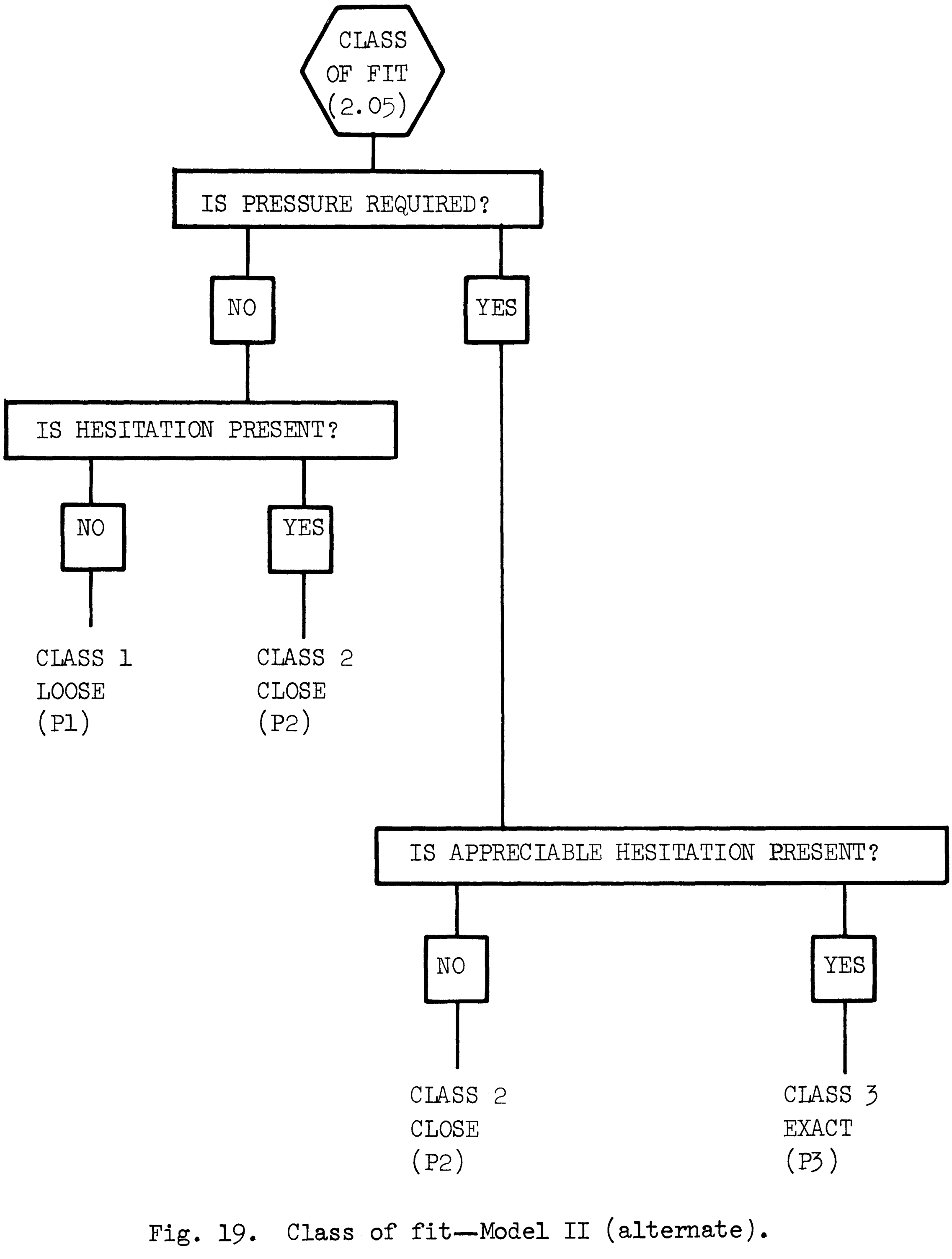


Fig. 19. Class of fit—Model II (alternate).

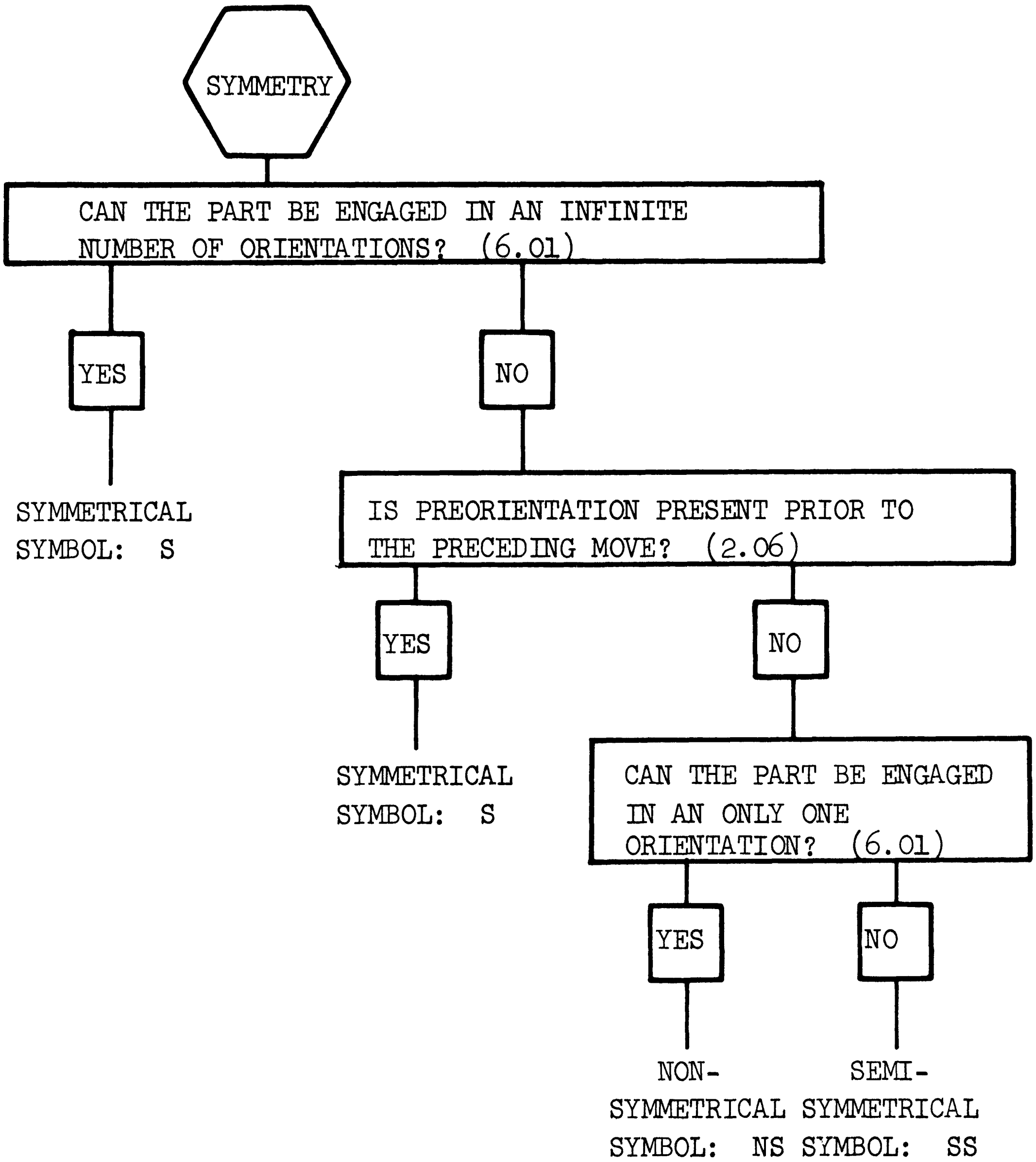


Fig. 20. Symmetry.

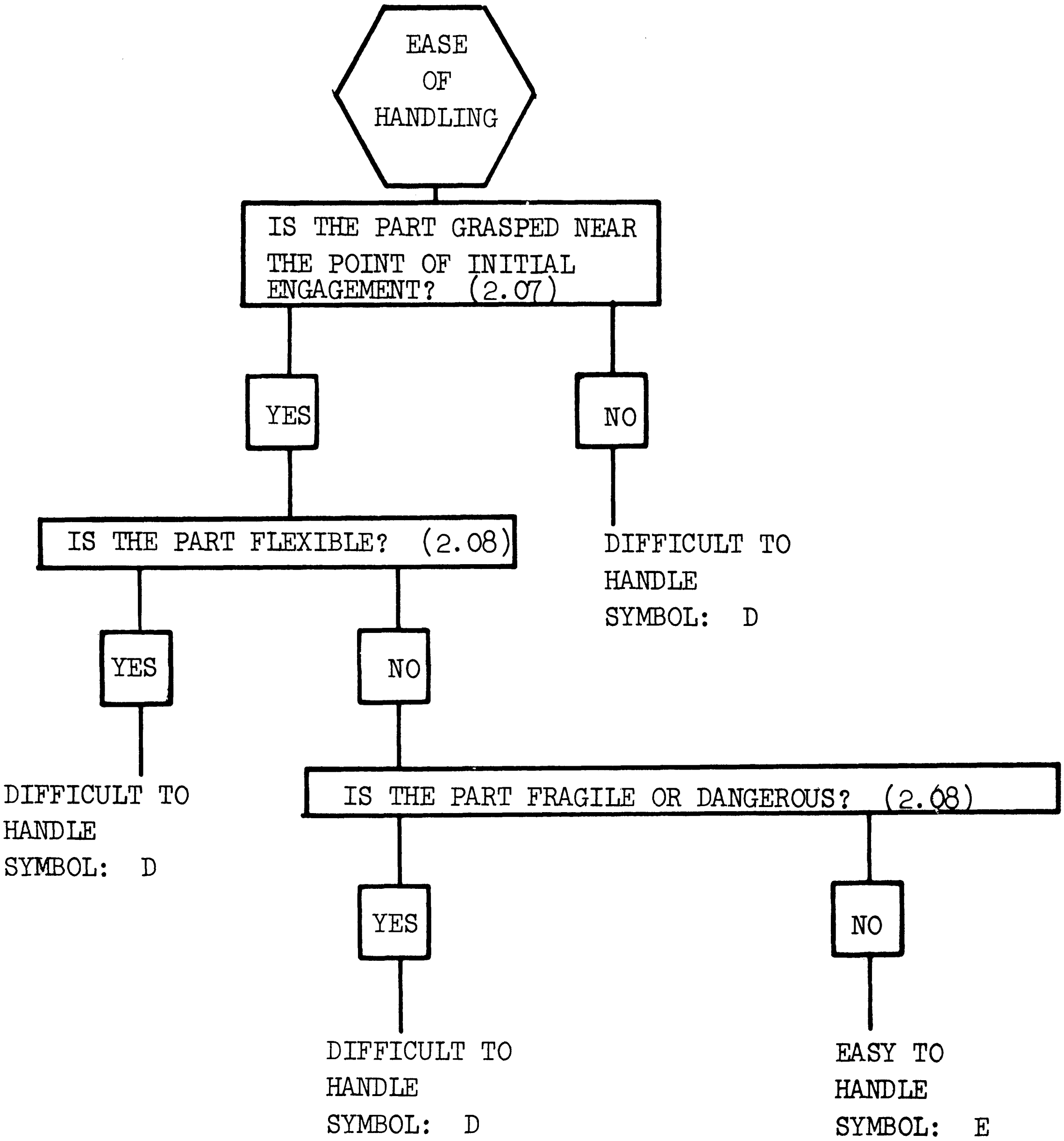


Fig. 21. Ease of handling.

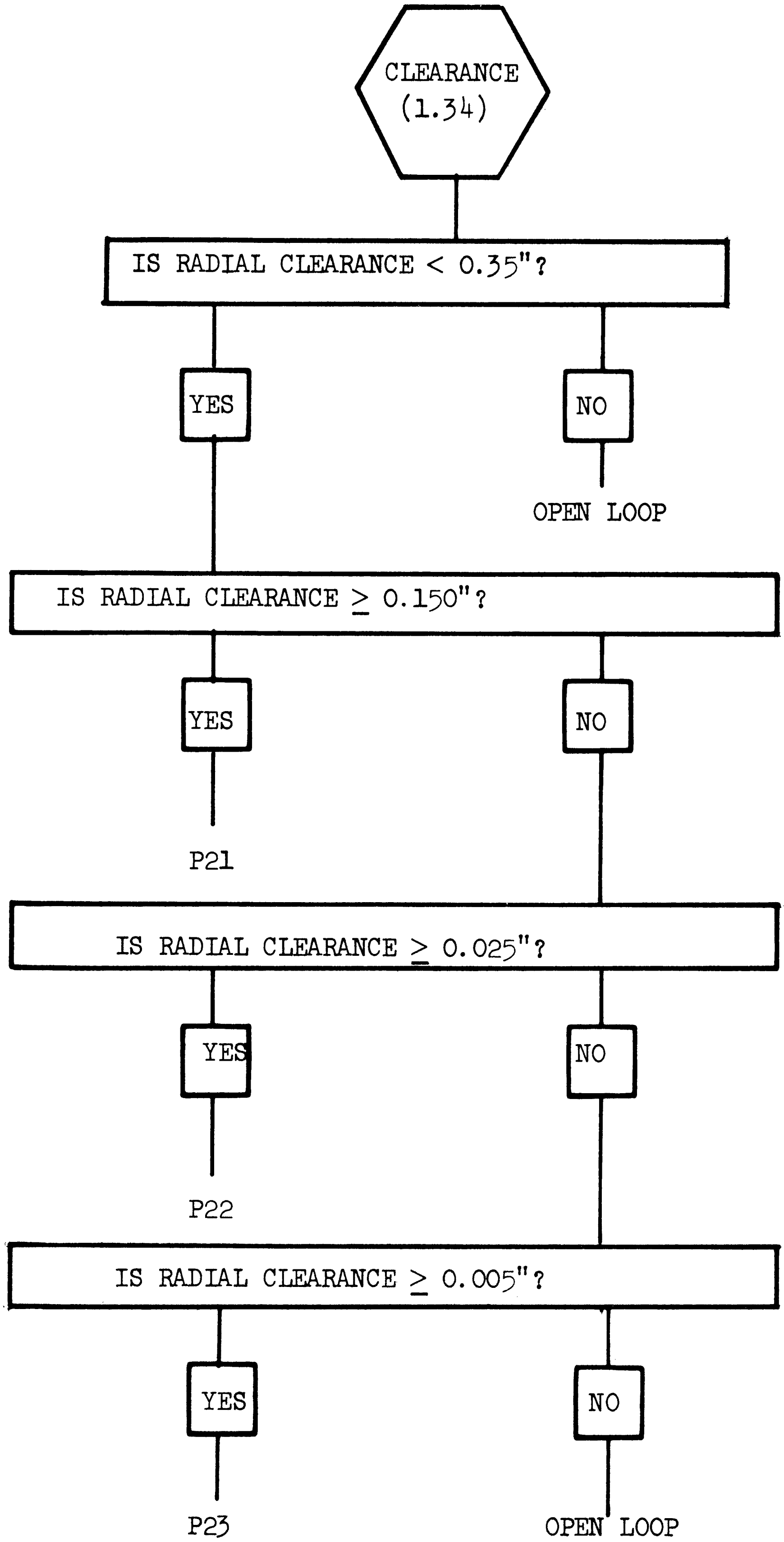


Fig. 22. Clearance.

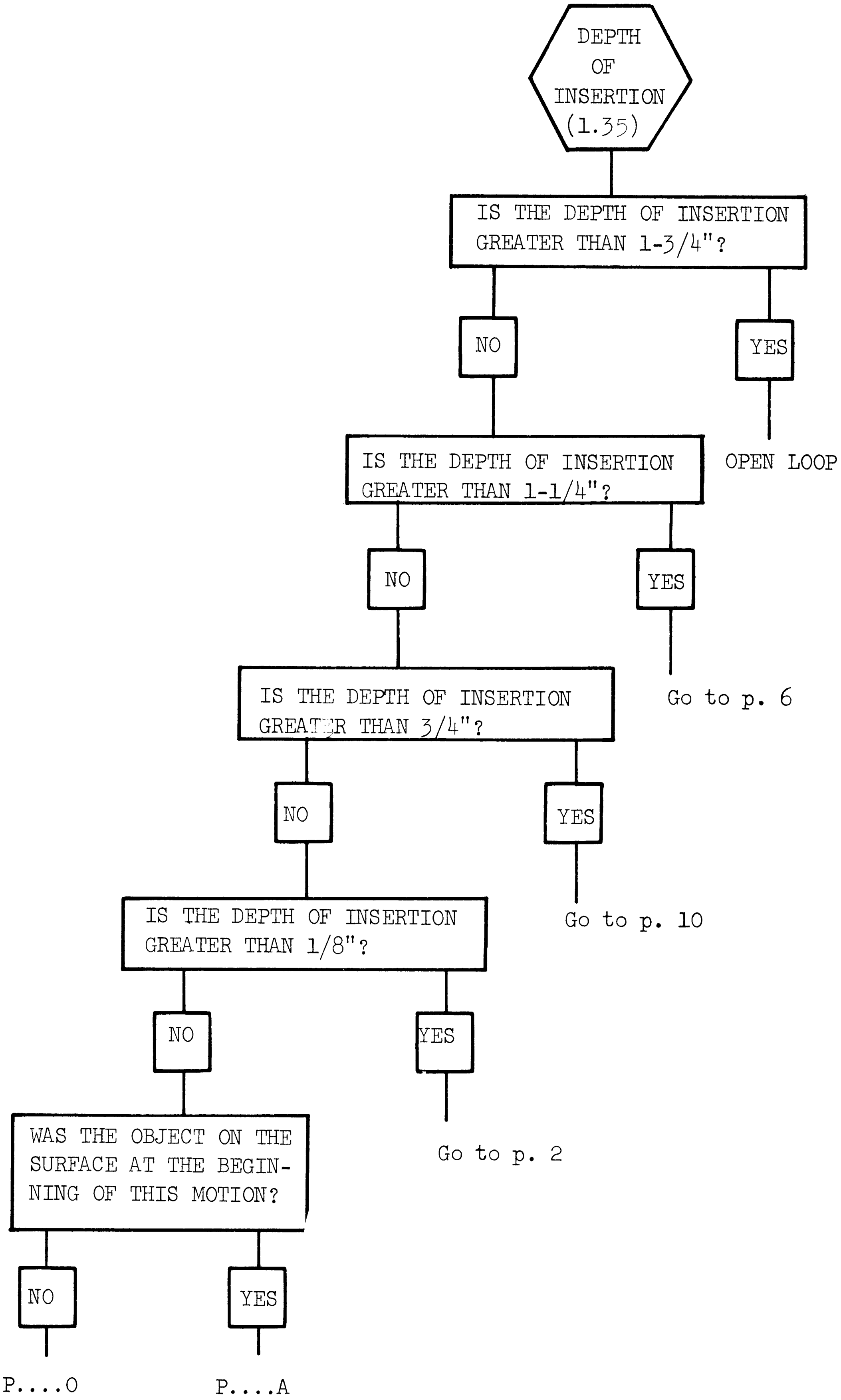


Fig. 23. Depth of insertion.

CHAPTER 10

DISENGAGE

DEFINITION: "Disengage is the basic hand or finger element employed to separate one object from another where there is a sudden ending of resistance.

1. Friction or recoil must be present. Merely lifting one object from the surface of another would not be a disengage.
2. There must be a noticeable break in the movement of the hand." (1.07)

Complete specification of the motion "disengage" consists of the following steps:

i) Determine "Class of Fit," e.g., D..1, D..2, etc. (Fig. 24)

ii) Determine "Ease of Handling," e.g., Easy to Handle (E), etc., Model I (Fig. 25) or Model II (Fig. 26)

iii) Determine "Care of Handling" (Fig. 27)

iv) Assign "Time Value" in TMU from MTM data card

Procedure: After determining from the main tree that the motion under consideration is "disengage," follow through the decision models as listed above in sequence and obtain the complete specifications of "disengage" with the corresponding time value.

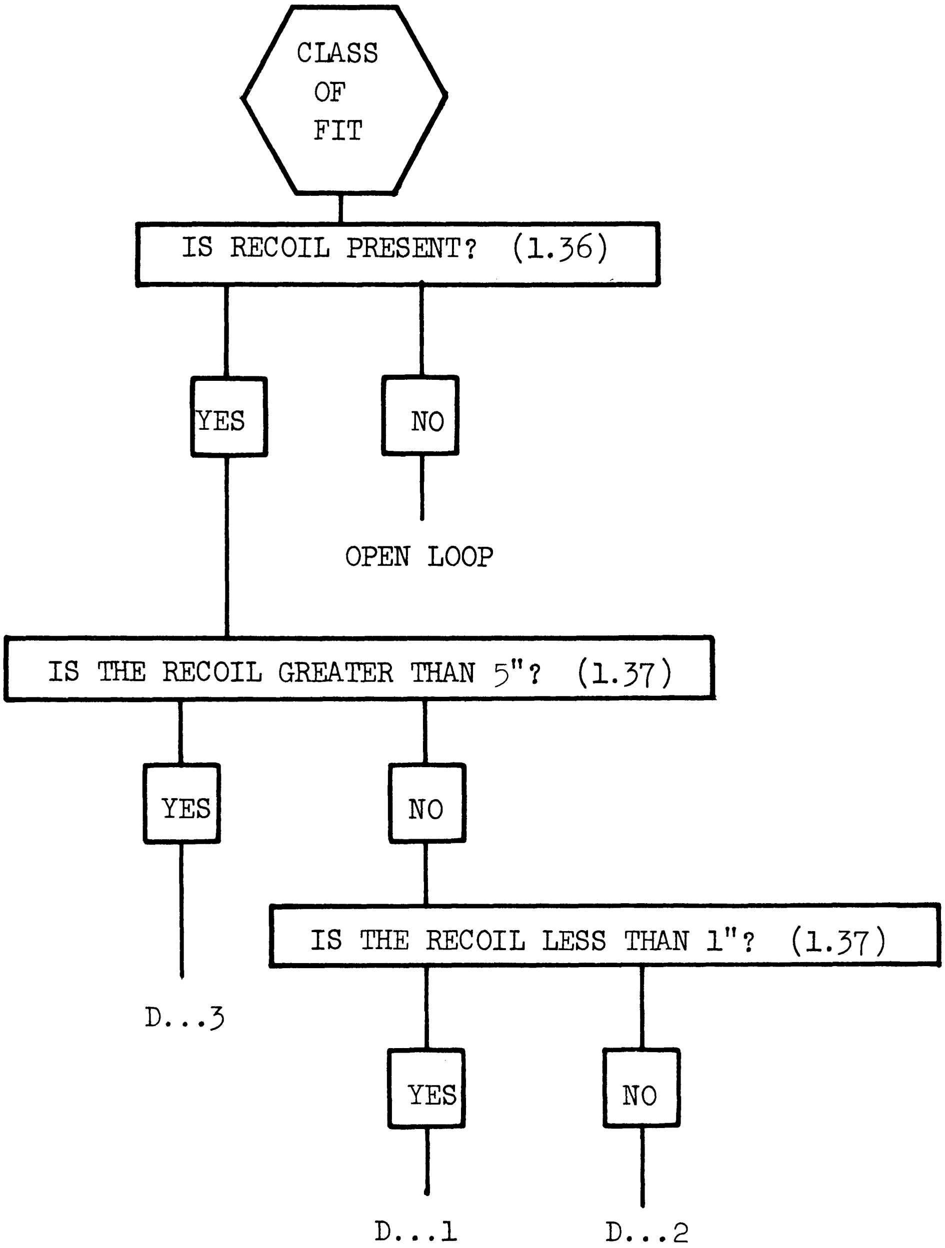


Fig. 24. Class of fit.

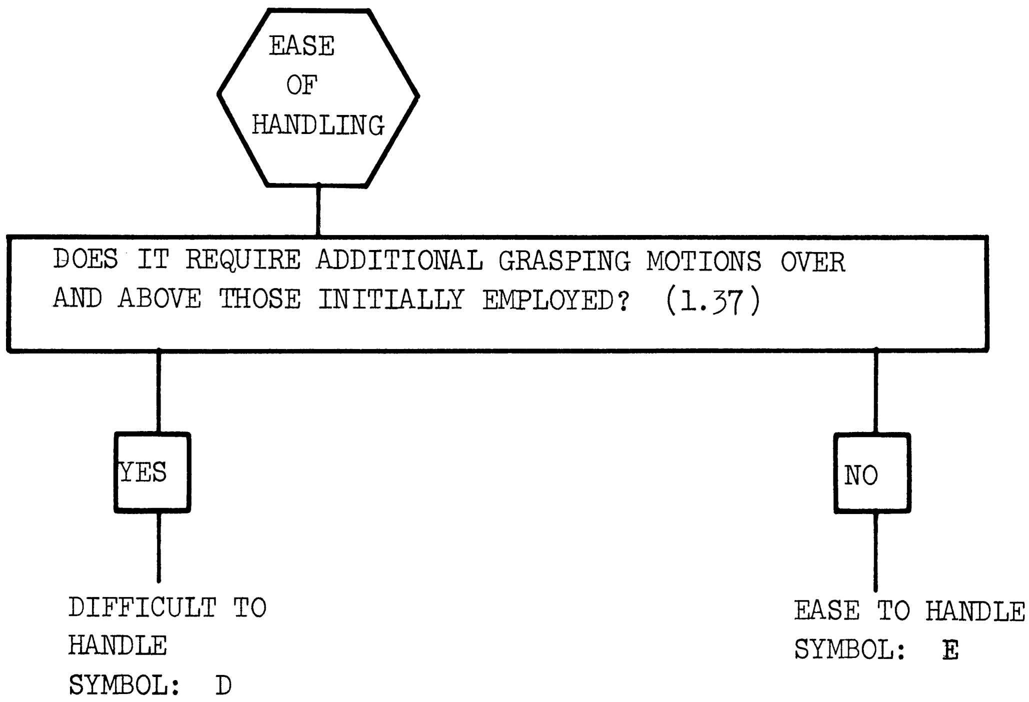


Fig. 25. Ease of handling—Model I.

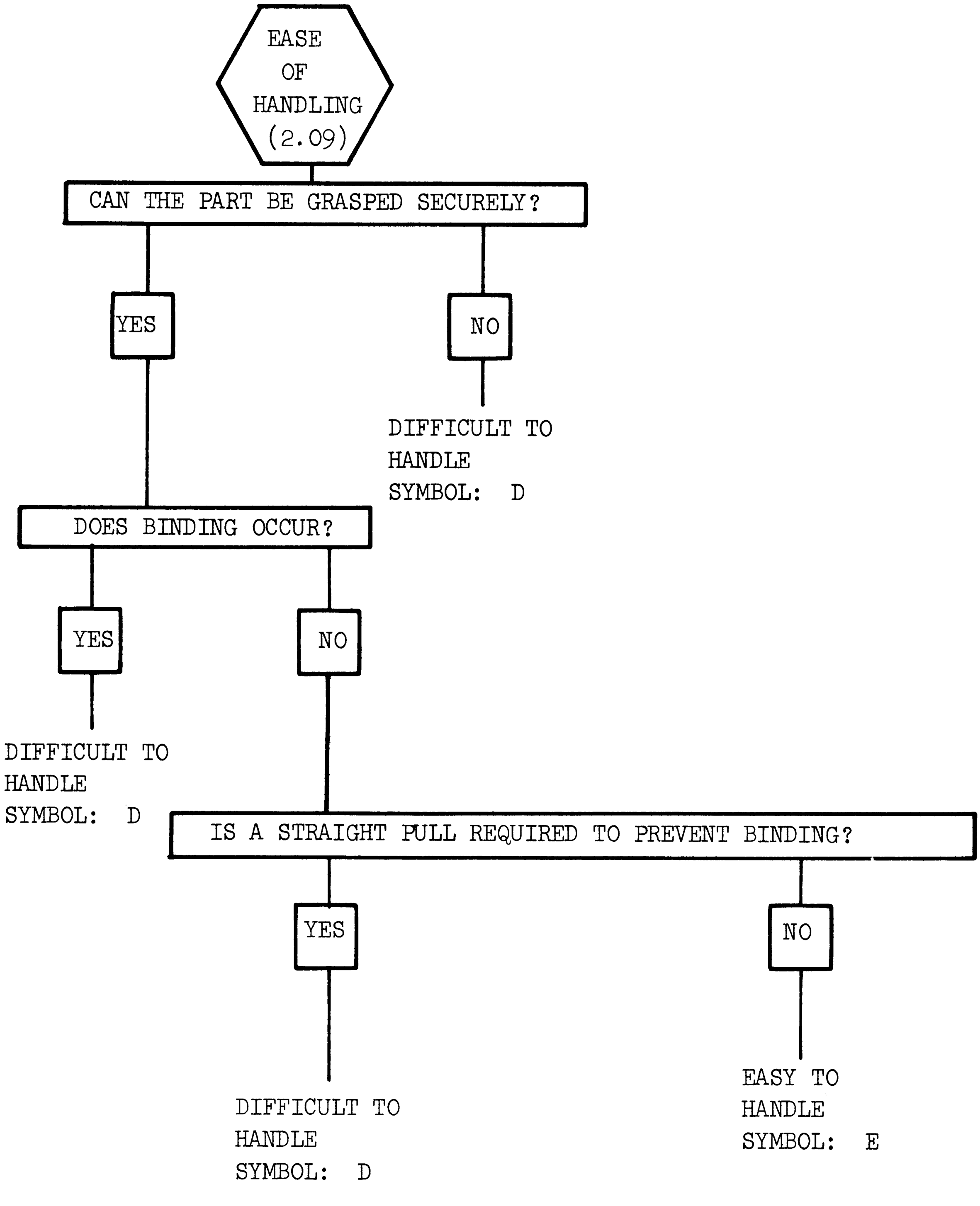


Fig. 26. Ease of handling—Model II (alternate).

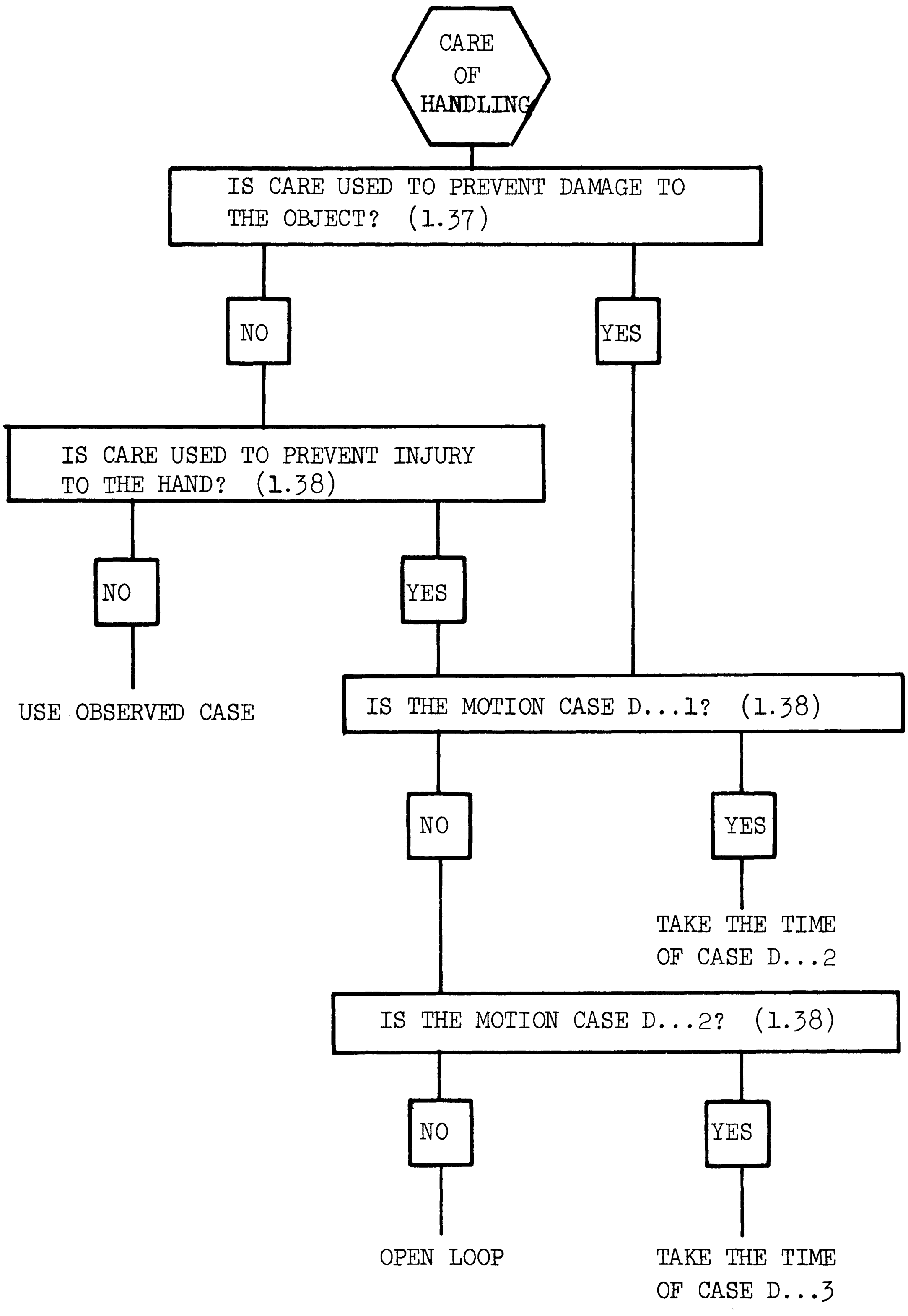


Fig. 27. Care of handling.

CHAPTER 11

EYE MOTION

DEFINITION:

1. Eye Focus - "Eye focus is the basic visual and mental element of looking at an object long enough to determine a readily distinguishable characteristic.
   (a) Eye focus is a hesitation while the eyes are examining some detail and transferring a mental picture to the brain.
   (b) The line of vision does not shift during the eye focus.
   (c) Eye focus is a limiting motion only when the eyes must identify the readily distinguishable characteristic before the next manual motion can be started." (1.39)
2. Eye Travel - "Eye travel is the basic eye motion employed to shift the axis of vision from one location to another.
   (a) Eye travel is a limiting motion only when the eyes must shift their axis of vision before the next motion can be started.
   Eye travel is only allowed when it is a limiting motion, that is, when the eyes must be shifted before the next motion can be performed." (1.40)

Eye motion time could be due to either "eye focus" or "eye travel." Therefore, complete specification of eye motion involves:

1) Determine whether it is "Eye Focus" - EF or "Eye Travel" - ET (Fig. 28)
2) Assign "Time Values" in TMU

i) For EF, from MTM data card

ii) For ET, compute by the formula ET time in TMU

$= 15.2 \times T/D$ with a maximum value of 20 TMU

where T = the distance between points from and to which the eye travels

D = the perpendicular distance from the eye to the line of travel T

Procedure: After determining from the main tree that the motion under consideration is "eye motion," follow through the decision model on the following page and obtain the complete specification of "eye motion" with the corresponding time value.

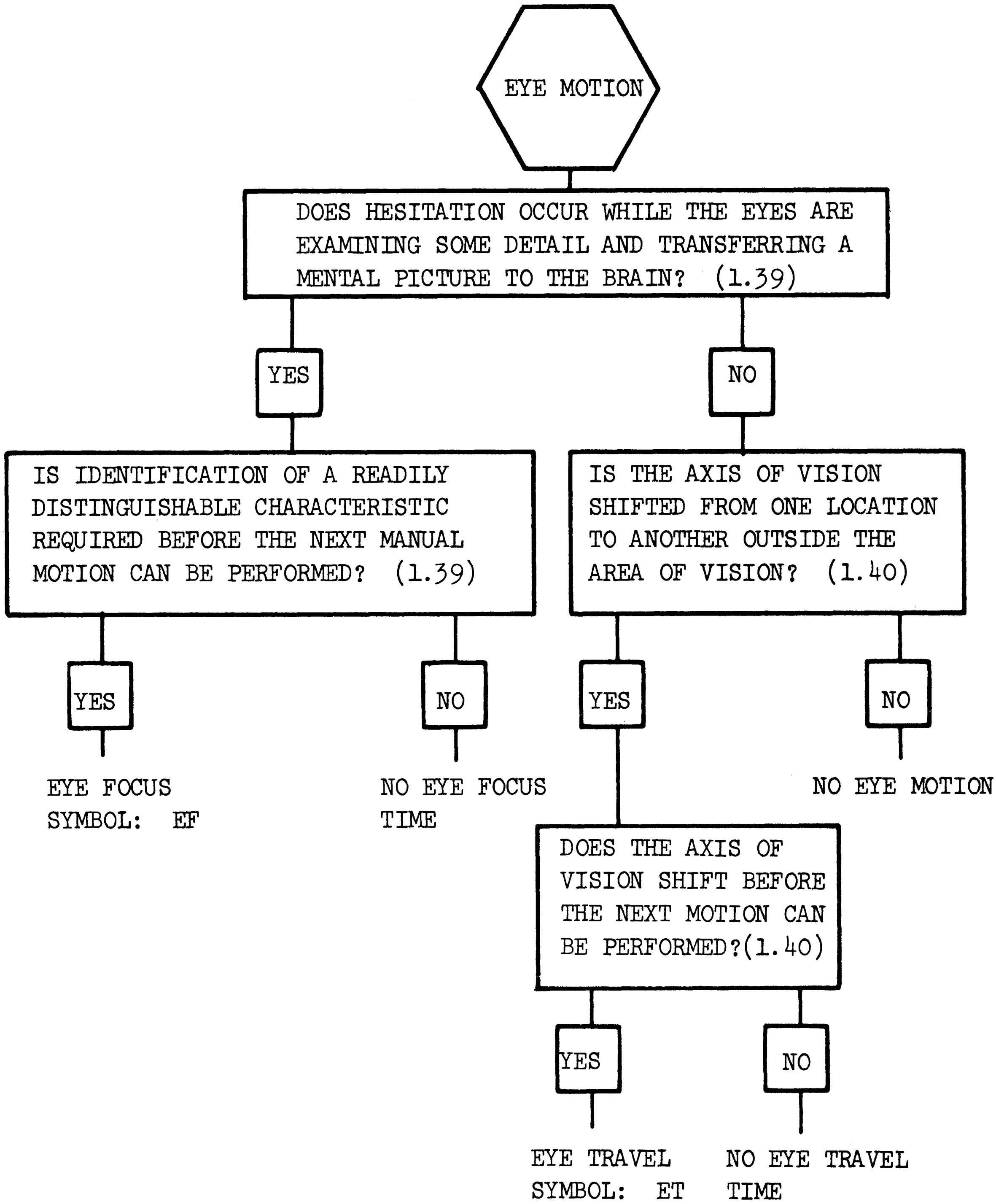


Fig. 28. Eye motion.

CHAPTER 12

BODY, LEG, AND FOOT MOTIONS

DEFINITIONS:

1. Walk: "Walking is a forward or backward movement of the body performed by alternate steps.

   (a) Walking does not include stepping to the side or turning around." (1.43)

2. Foot Motion: "Foot motion is the movement of the ball of the foot up or down with the heel or the instep serving as a fulcrum.

   (a) Motion of toes of foot generally is 2" to 4".

   (b) Foot motion, with pressure includes a hesitation for the application of force directly by the foot or a transfer of body weight in conjunction with the foot motion." (1.53)

3. Leg Motion: "Leg motion is the movement of the leg in any direction with the knee or the hip as the pivot, where the predominant purpose is to move the foot rather than the body.

   (a) Leg motion may be made while either sitting or standing.

   (b) Leg motion made while standing usually has the hip as the major pivoting point.

   (c) Leg motion made while sitting usually has the knee as the major pivoting point." (1.46)

4. Side Step: "Side step is a lateral motion of the body, without rotation, performed by one or two steps.

(a) The body moves directly to the side without any noticeable raising or lowering or rotation." (1.42)

5. Turn Body: "Turn body is a rotational movement of the body performed by one or two steps.

   (a) In performing the turn body, the steps are made with the feet turning in the same direction as the body." (1.41)

6. Bend: "Bend is the motion of lowering the body in a forward arc, from standing position, so that the hands can reach to or below the level of the knees.

   (a) Bend is performed with little or no rotation of the body or flexing of the knees.

   (b) Bend is controlled by the back muscles and leg muscles.

   Bend is a conscious lowering of the upper part of the body—and the back muscles are controlling the motion.

   Bend should not be confused with body assist." (1.49)

7. Stoop: "Stoop is the motion of lowering the body in a forward arc from a standing position, so that the hands can reach to the floor.

   (a) Stoop is performed by bowing forward at the hips and at the same time lowering the entire body by bending at the knees.

   (b) Stoop lowers the hands further than bend through a simultaneous "bend" and knee bend." (1.48)

8. Kneel on One Knee: "Kneel on one knee is the motion of lowering the body from erect standing position by shifting one foot forward or backward and lowering one knee to the floor.

(a) At the completion of kneel on one knee the weight of the body is supported on one knee and one foot with the other foot helping maintain balance." (1.48)

9. Kneel on Both Knees: "Kneel on both knees is the motion of lowering the body from erect standing position by shifting one foot forward or backward, lowering one knee to the floor, and placing the other knee adjacent to it.

   (a) At the completion of kneel on both knees the body is supported by both knees with the feet helping maintain balance." (1.50)

10. Arise from Bend: "Arise from bend is the motion of returning the body from a bend to an erect standing position." (1.45)

11. Arise from Stoop: "Arise from stoop is the motion of returning the body from stoop to an erect standing position." (1.45)

12. Arise from Kneel on One Knee: "Arise from kneel on one knee is the motion of returning the body from kneel on one knee to an erect standing position." (1.45)

13. Arise from Kneel on Both Knees: "Arise from kneel on both knees is the motion of returning the body from kneel on both knees to an erect standing position." (1.44)

14. Sit: "Sit is the motion of lowering the body from an erect standing position directly in front of the seat and transferring the weight of the body to the seat.

   (a) At the completion of sit, the weight of the body is supported by the seat.

(b) Sit does not include such motions as stepping in front of the chair or shifting position of the chair." (1.44)

15. Stand: "Stand is the motion of transferring the weight of the body from the seat and raising the body to an erect standing position directly in front of the seat.

(a) Stand does not include such motions as shifting the position of the chair or stepping to the side of the chair." (1.44)

Any one of the motions defined in this chapter (1 through 15) will be categorized under the general heading of "Body, Leg, and Foot" motions. Complete specification of a "body, leg, and foot" motion would therefore, consist of the following steps:

i) Determine type of motion, e.g., "Bend" - B, "Stoop" - S, etc. (Fig. 29)

ii) Assign "Time Values" in TMU for MTM data card

Procedure: After determining from the main tree that the motion under consideration falls under "body, leg, and foot" motions, follow through the decision model beginning on the following page and obtain the complete specification of the motion with the corresponding time value.

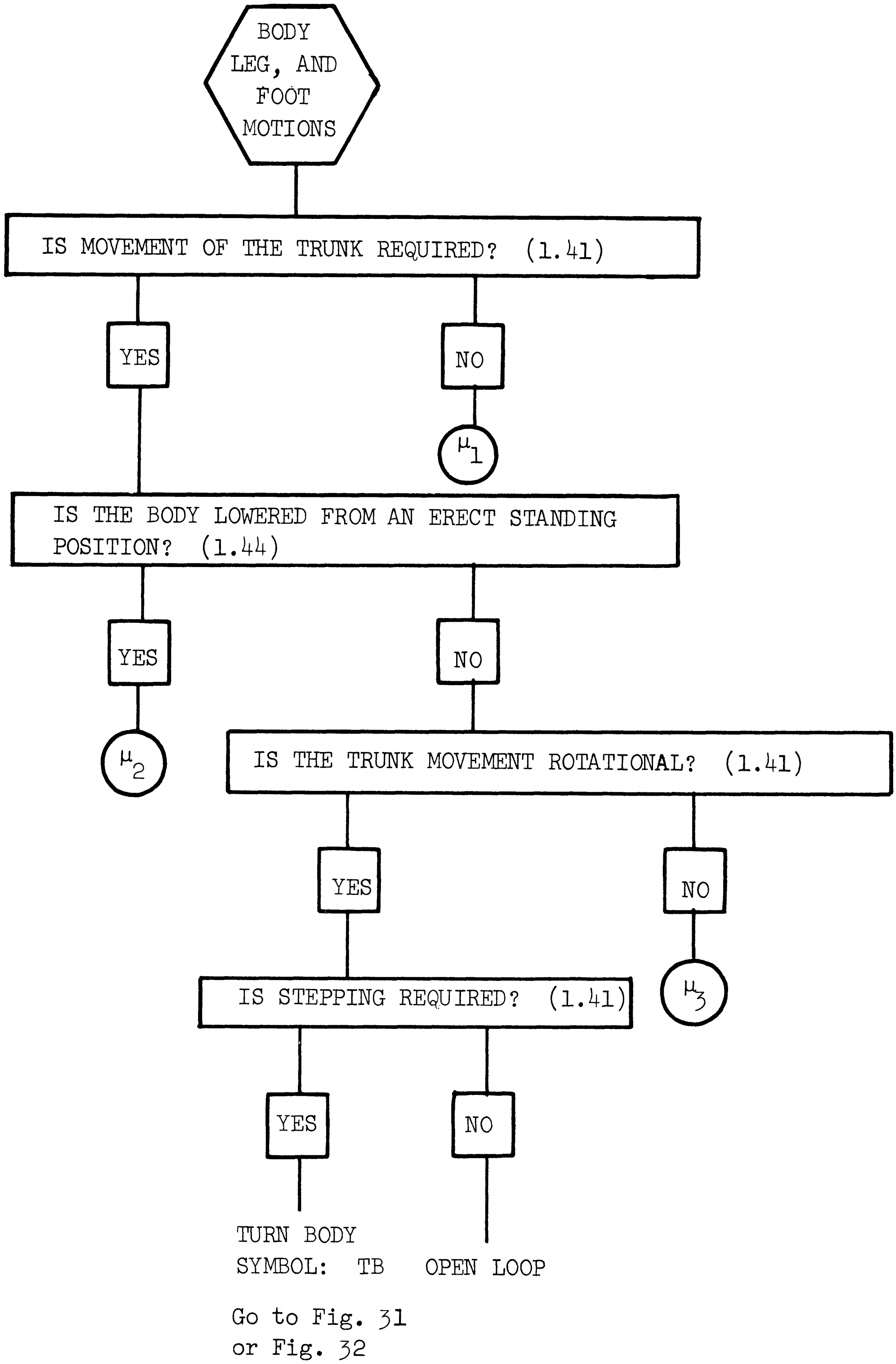


Fig. 29. Body, leg, and foot motions.

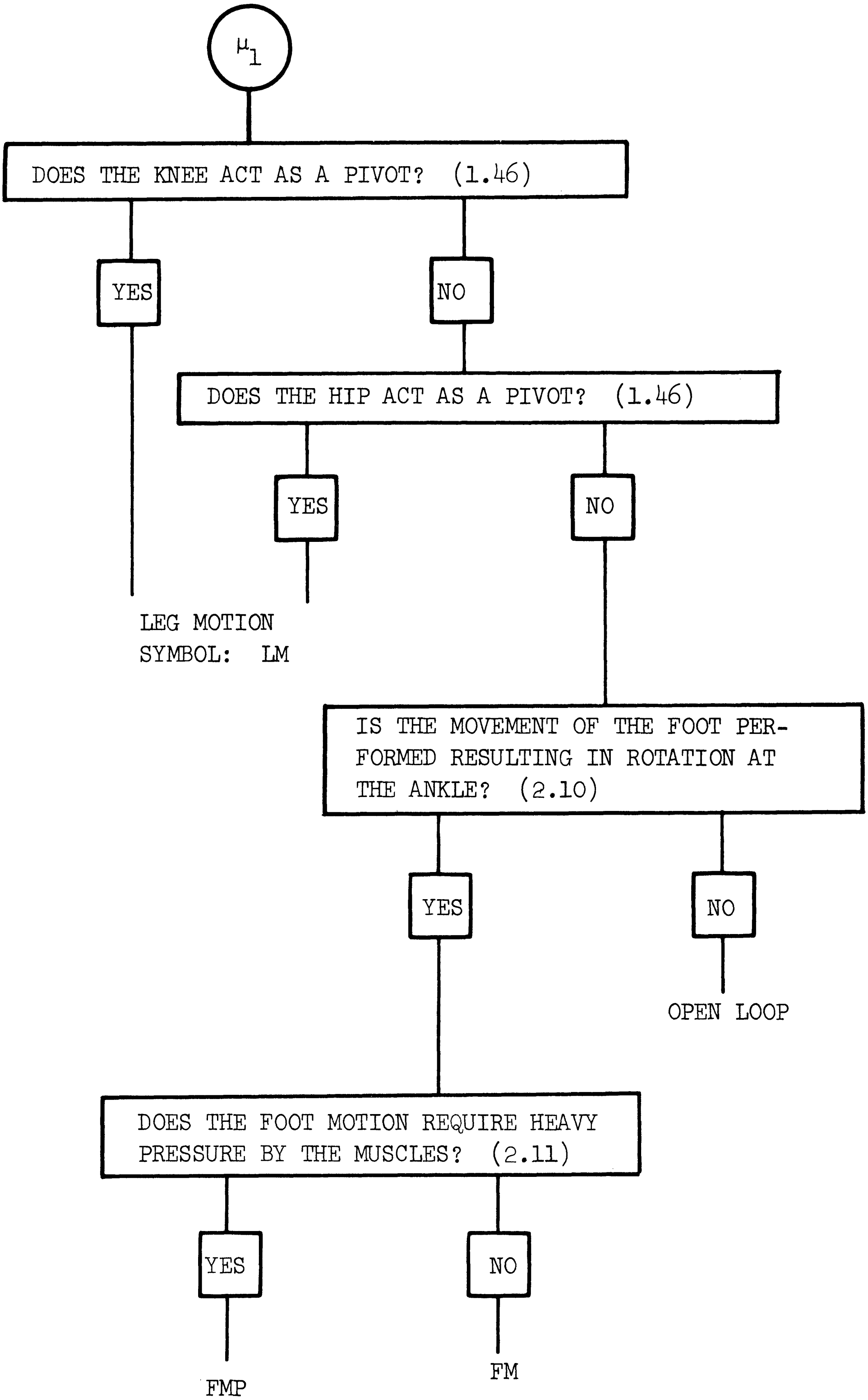


Fig. 29. (Continued).

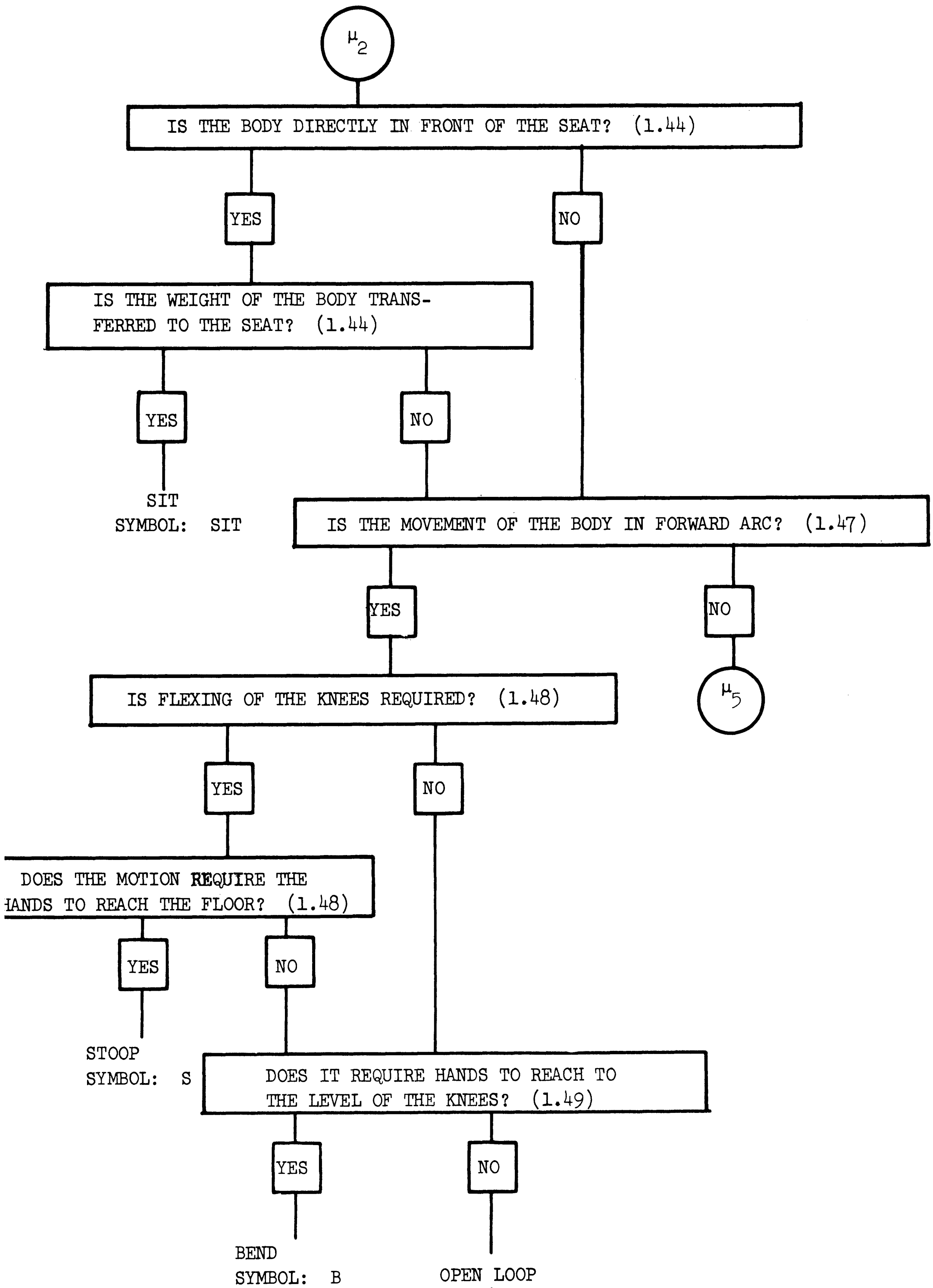


Fig. 29. (Continued).

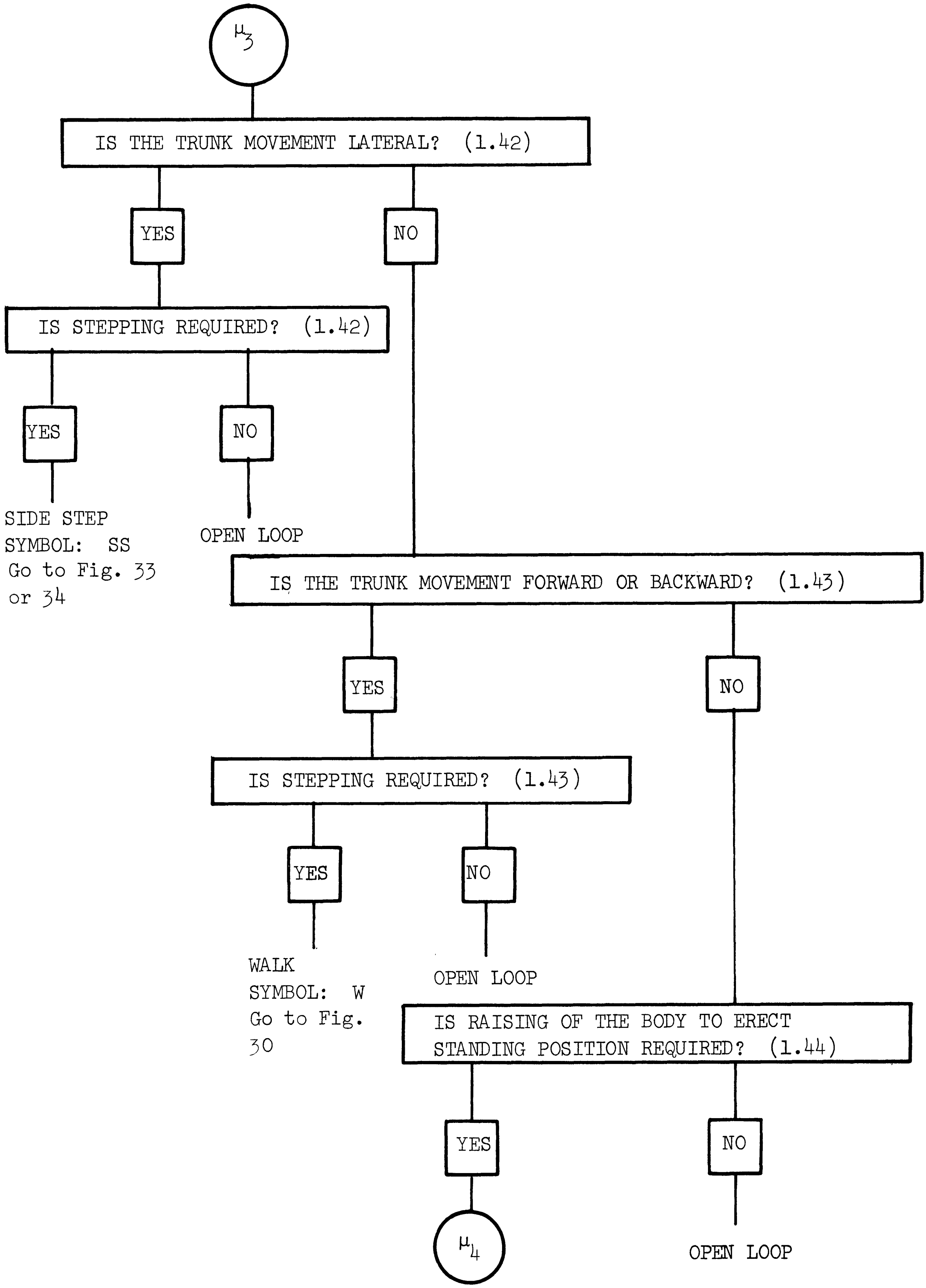


Fig. 29. (Continued).

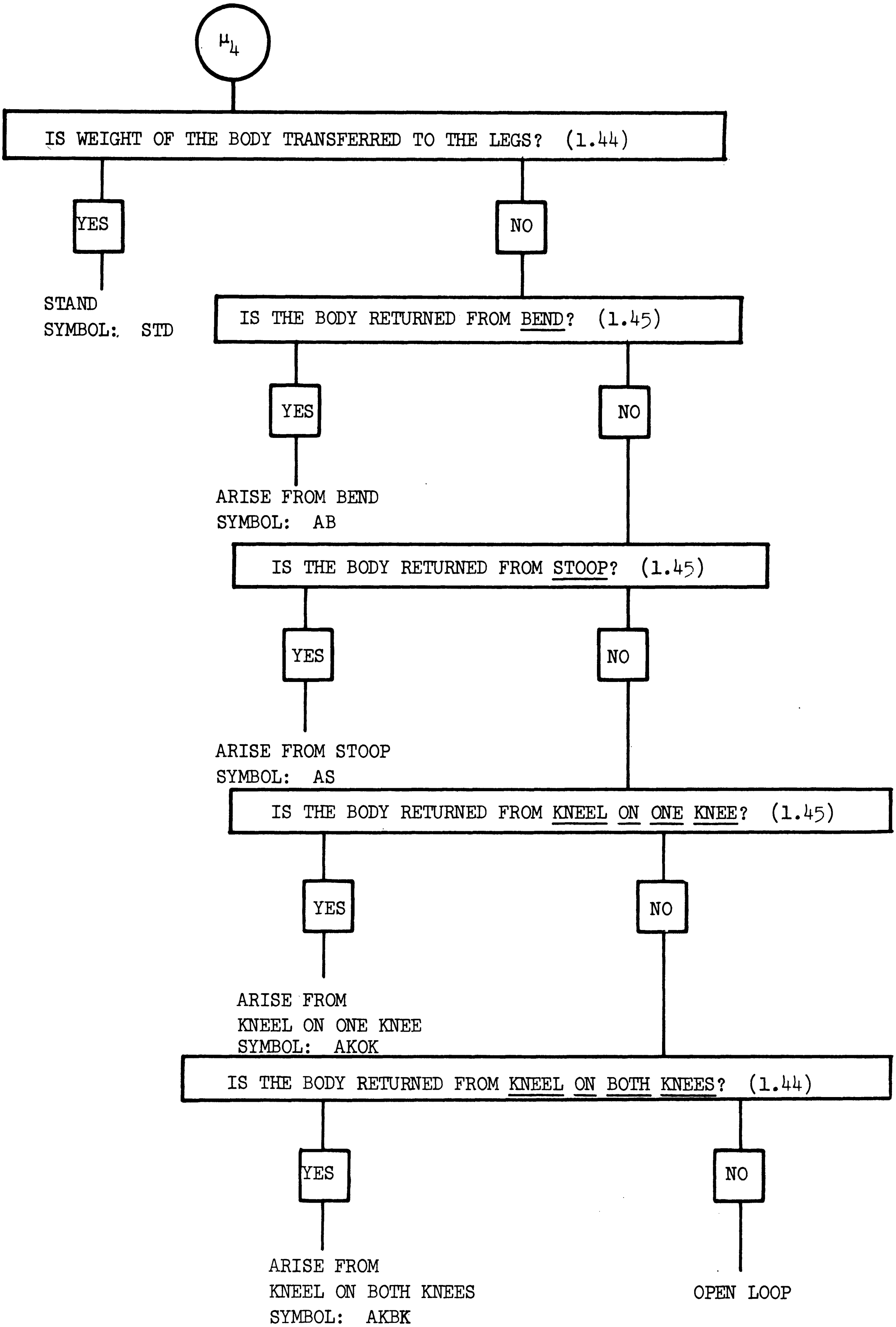


Fig. 29. (Continued).

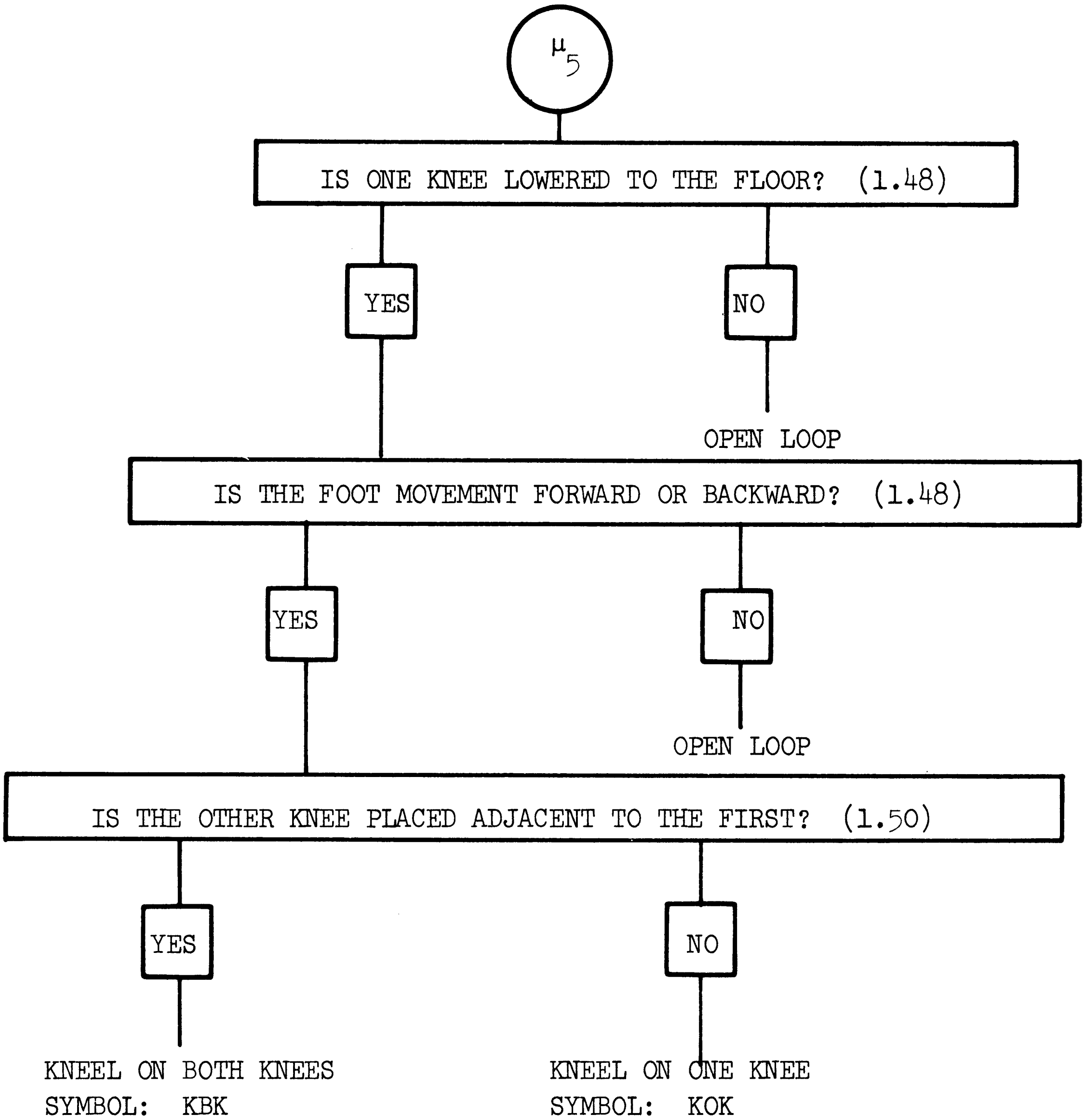


Fig. 29. (Concluded).

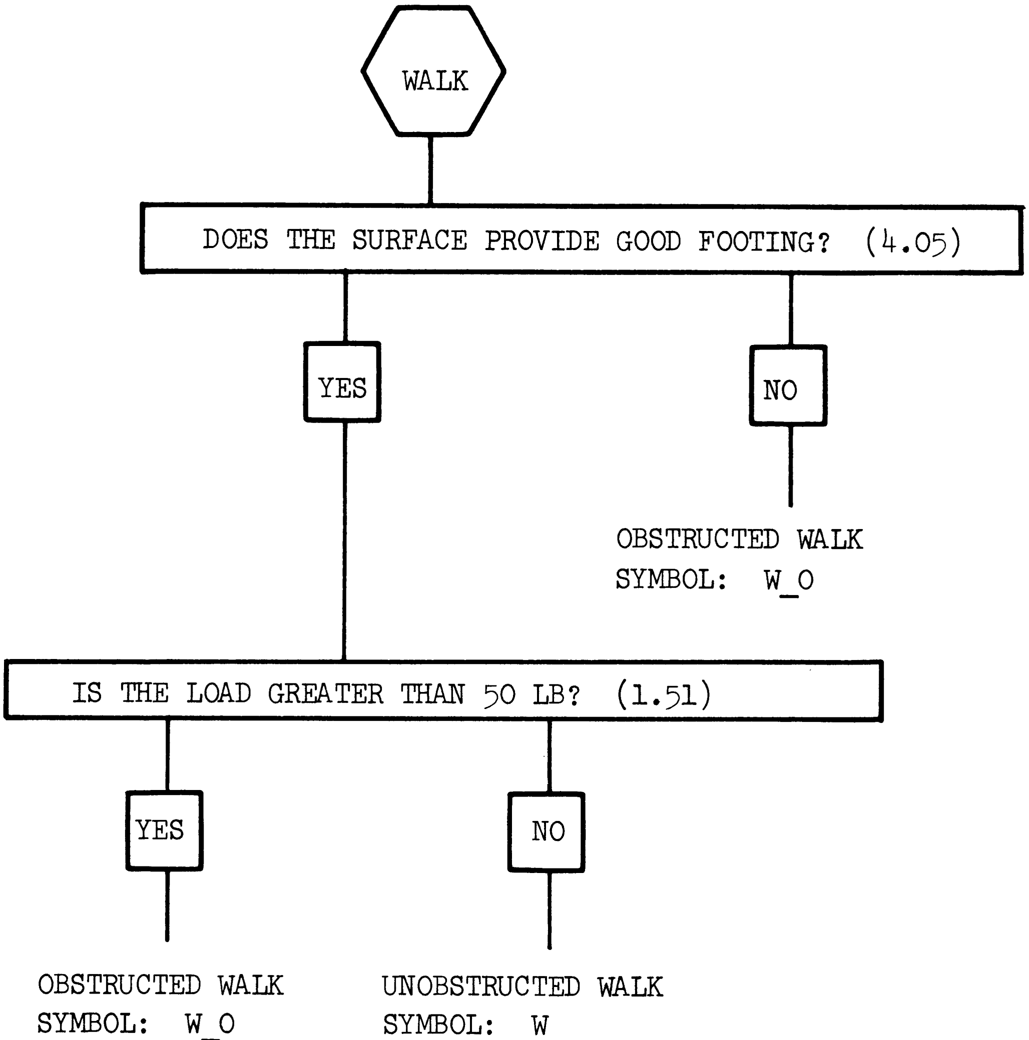


Fig. 30. Walk—case.

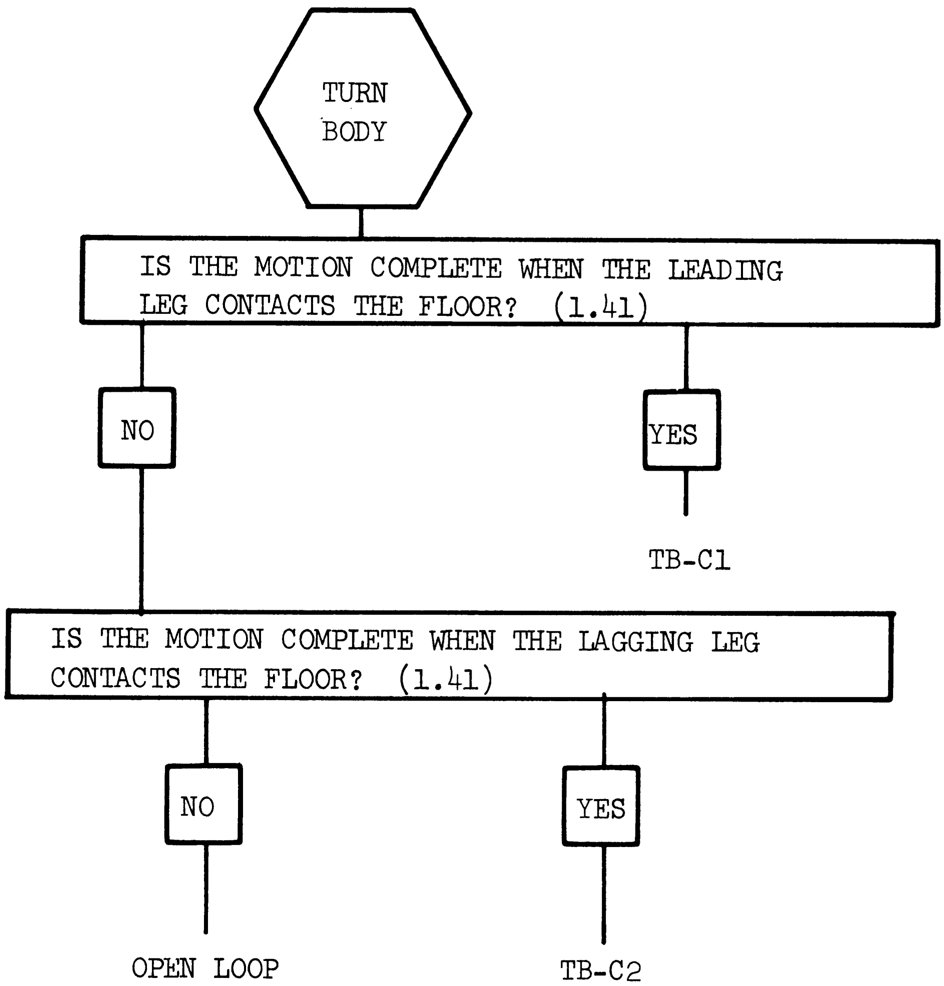


Fig. 31. Turn body—case—Model I.

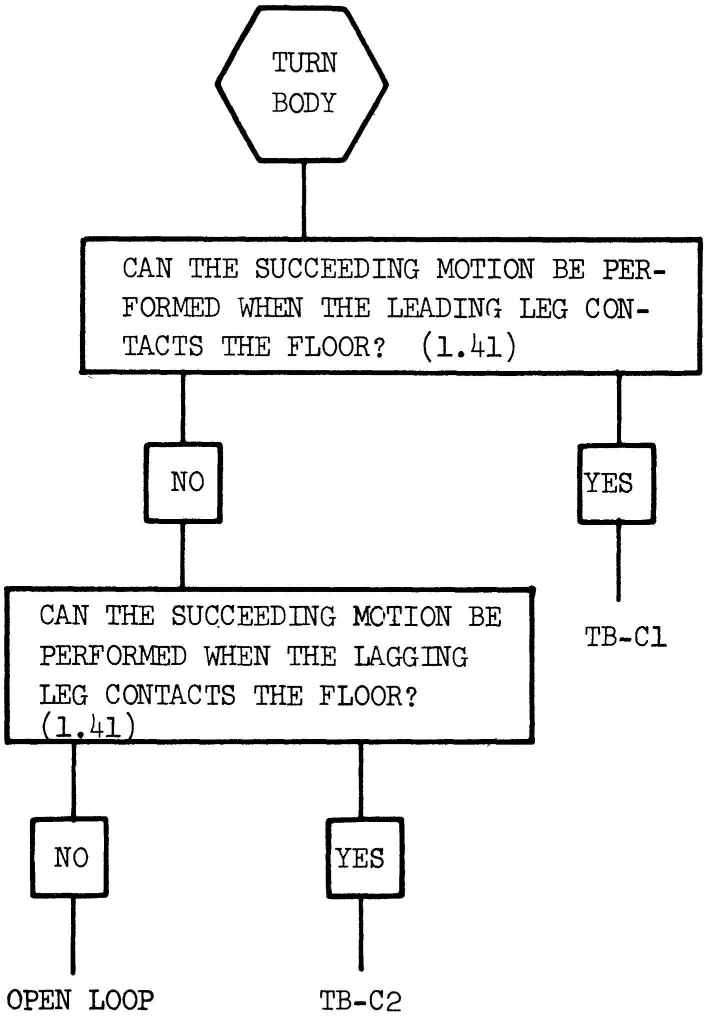


Fig. 32. Turn body—case—Model II (alternate).

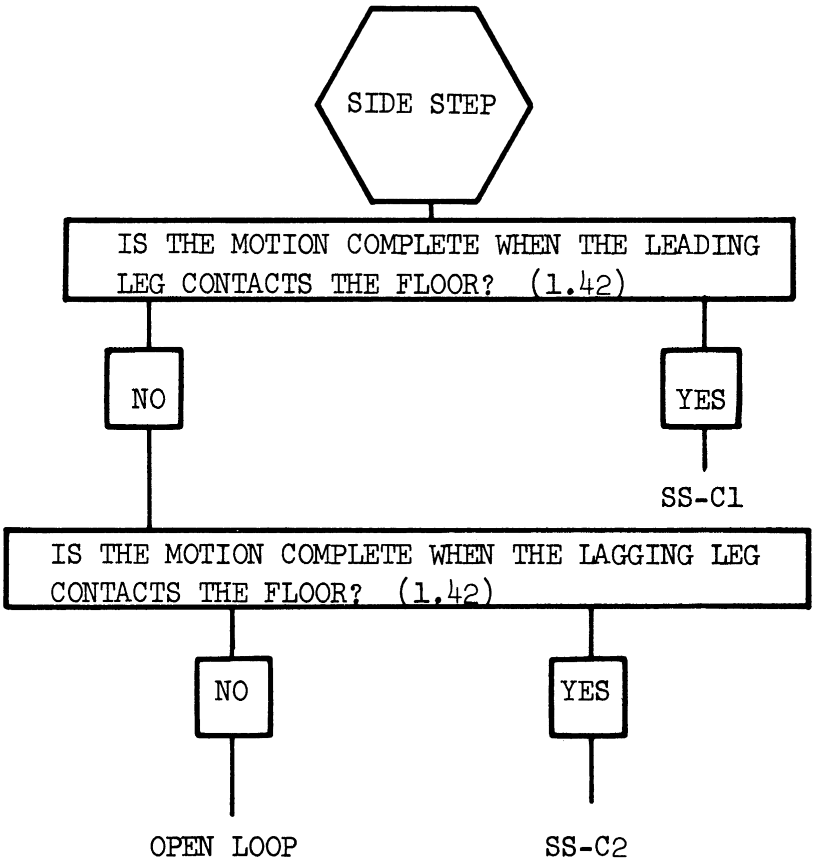


Fig. 33. Side step—case—Model I.

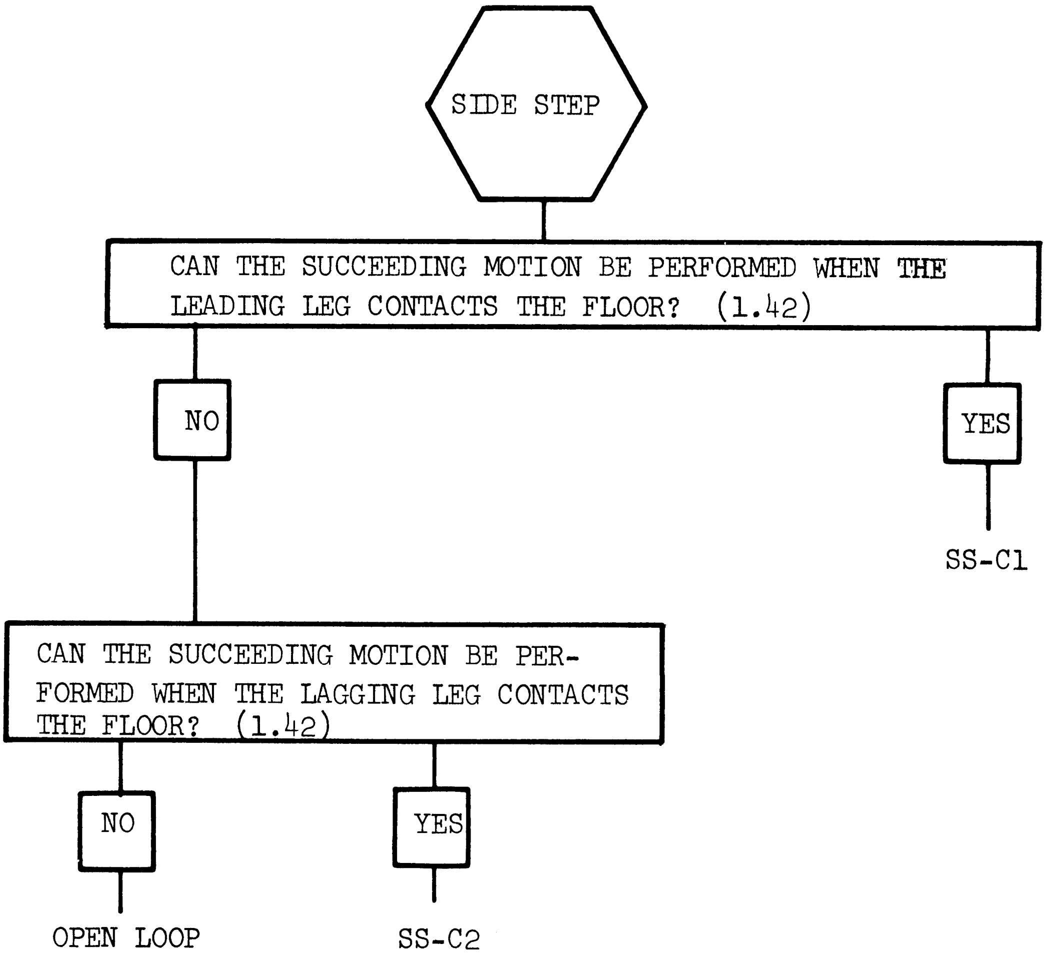


Fig. 34. Side step—case—Model II (alternate).

CHAPTER 13

CRANKING

DEFINITION: "Motion of the fingers, hand, wrist, and forearm in a circular path, with the forearm pivoting at the elbow." (1.09)

Complete specification of the motion "cranking" consists of the following steps:

i) Determine "Type" of cranking, e.g., "Continuous Heavy Cranking"— N C d-w, etc., (Fig. 35)

ii) Compute "Time Value" in TMU using appropriate formulae

One of the following set of formulae is used to compute the time value for "cranking."

Formula 13.1 - Continuous Light Crank

$$\text{Cranking TMU} = (N)(T) + 5.2$$

where N = number of revolutions

Let d = diameter of crank in in.

T = each additional revolution time corresponding to 'd' from table in MTM-ATC manual (1.00) p - day V - 11

Formula 13.2 - Intermittent Light Crank

$$\text{Cranking TMU} = [(T + 5.2)N_1] + [(N_2)(T) + 5.2]$$

where N_1 = integer part of N

N_2 = fraction part of N

other symbols as defined before.

Formula 13.3 - Continuous Heavy Crank

Cranking TMU = $[(N)(T) + 5.2]\ F + C$

Let W = cranking load in pounds tangential to the grasping point

F = Dynamic Component (D.C.) of the weight factor as given for "move" in MTM data card corresponding to W

C = Static Component (S.C.) of the weight factor as given for "move" in MTM data card corresponding to W

other symbols as defined before.

Formula 13.4 - Intermittent Heavy Crank

Cranking TMU = $[(T + 5.2)F + C]N_1 + [(N_2)(T) + 5.2]F + C$

where the symbols have the same interpretation.

Procedure: After determining from the main tree that the motion under consideration is "cranking," follow through the decision model (Fig. 35) and obtain the complete specification of the motion with the corresponding time value.

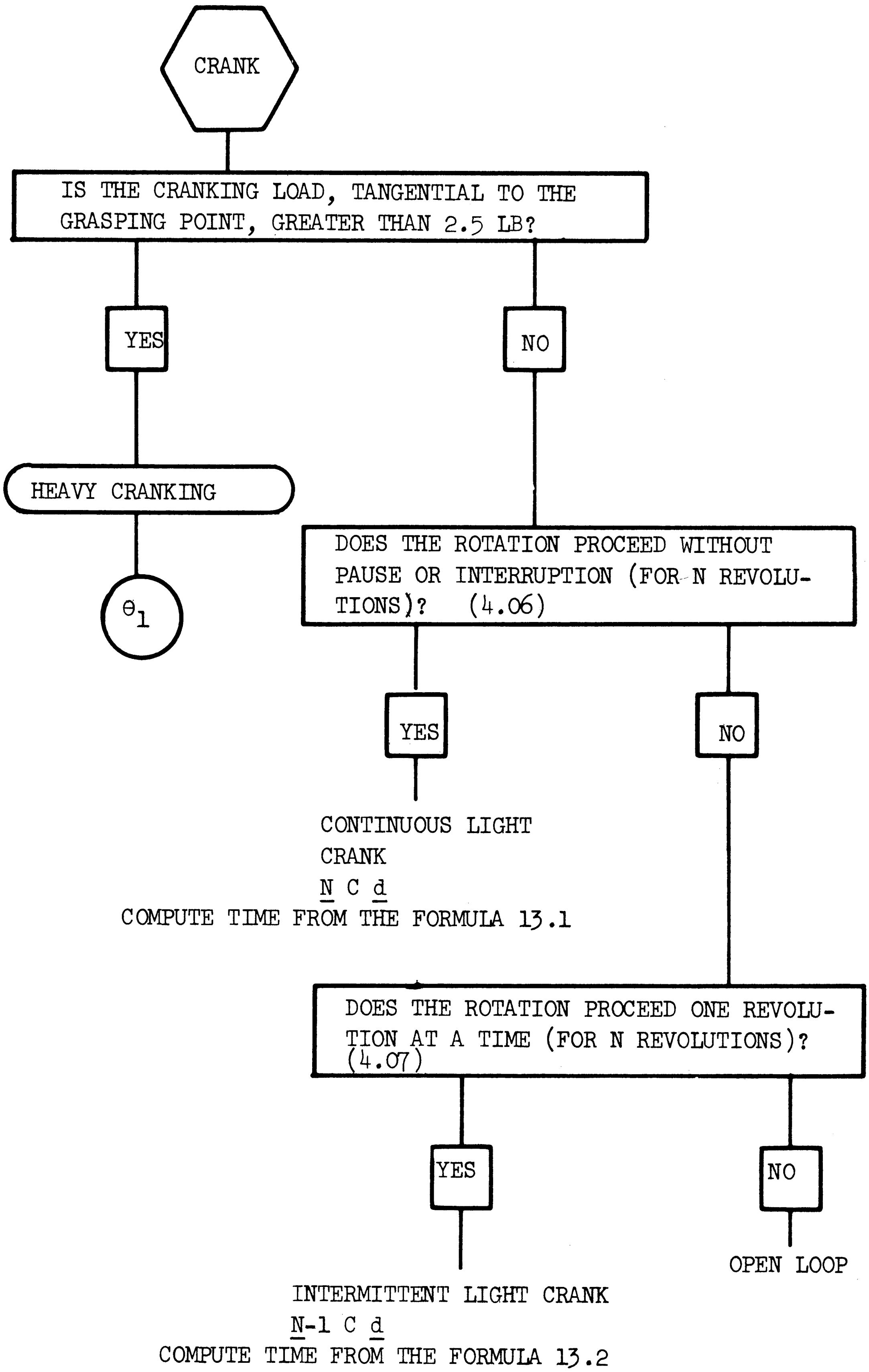


Fig. 35. Cranking—type.

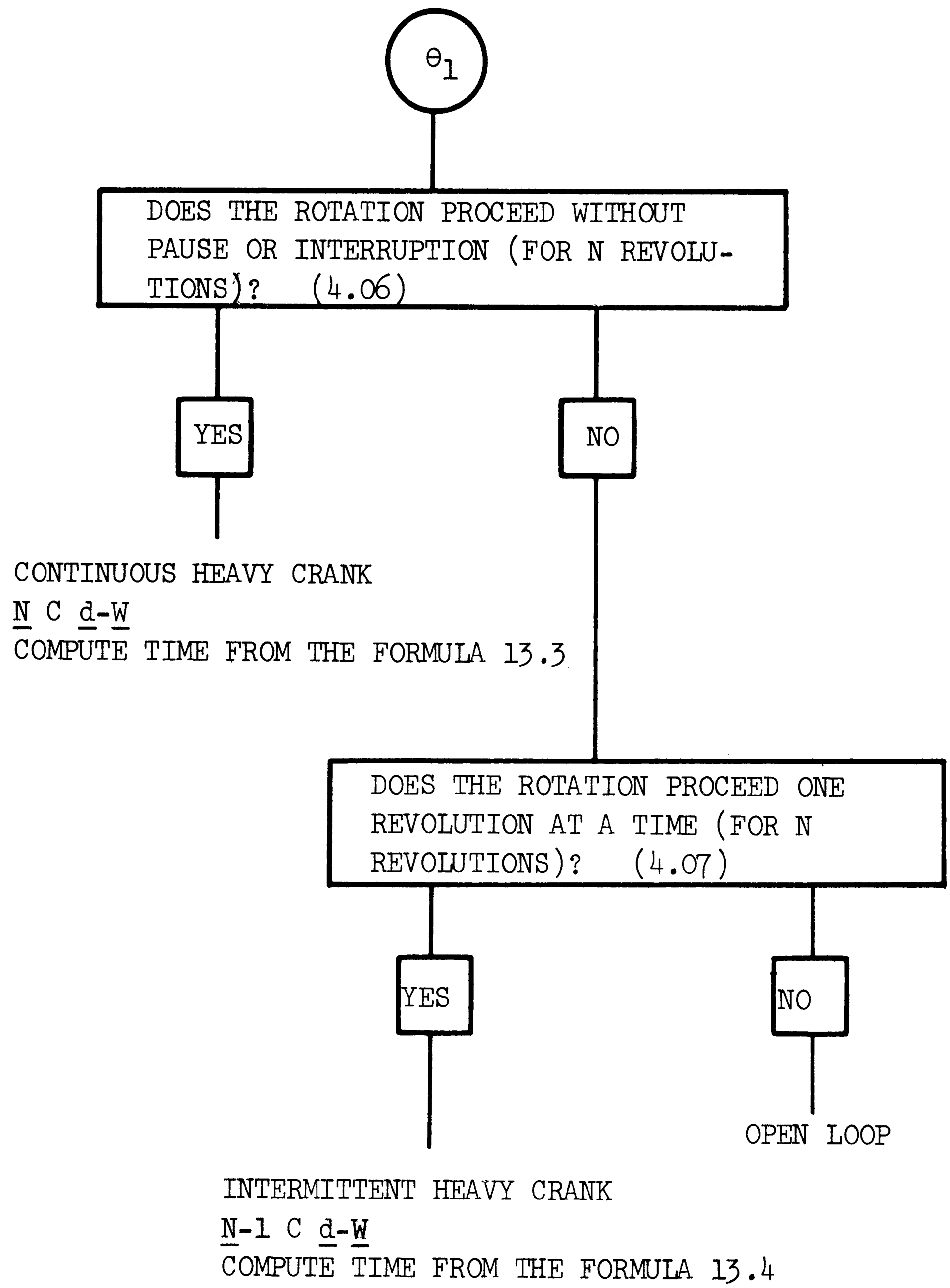


Fig. 35. (Concluded).

CHAPTER 14

MOTION COMBINATIONS

DEFINITIONS:

1. Combined Motions: "Two or more motions performed at the same time by the same body member." (1.54)
2. Simultaneous Motions: "Two or more motions performed at the same time by different body members." (1.54)
3. Limiting Motion: "The motion requiring the greatest amount of time is the limiting motion." (1.54)

"Motion-Combination" can be characterized by any of the above listed patterns.

Procedure: After determining the complete motion specifications with the corresponding time values separately for all the motions under consideration, take one motion at a time and follow through the decision model (Figs. 36 and 37) to ascertain which of these motions will effect the total cycle time.

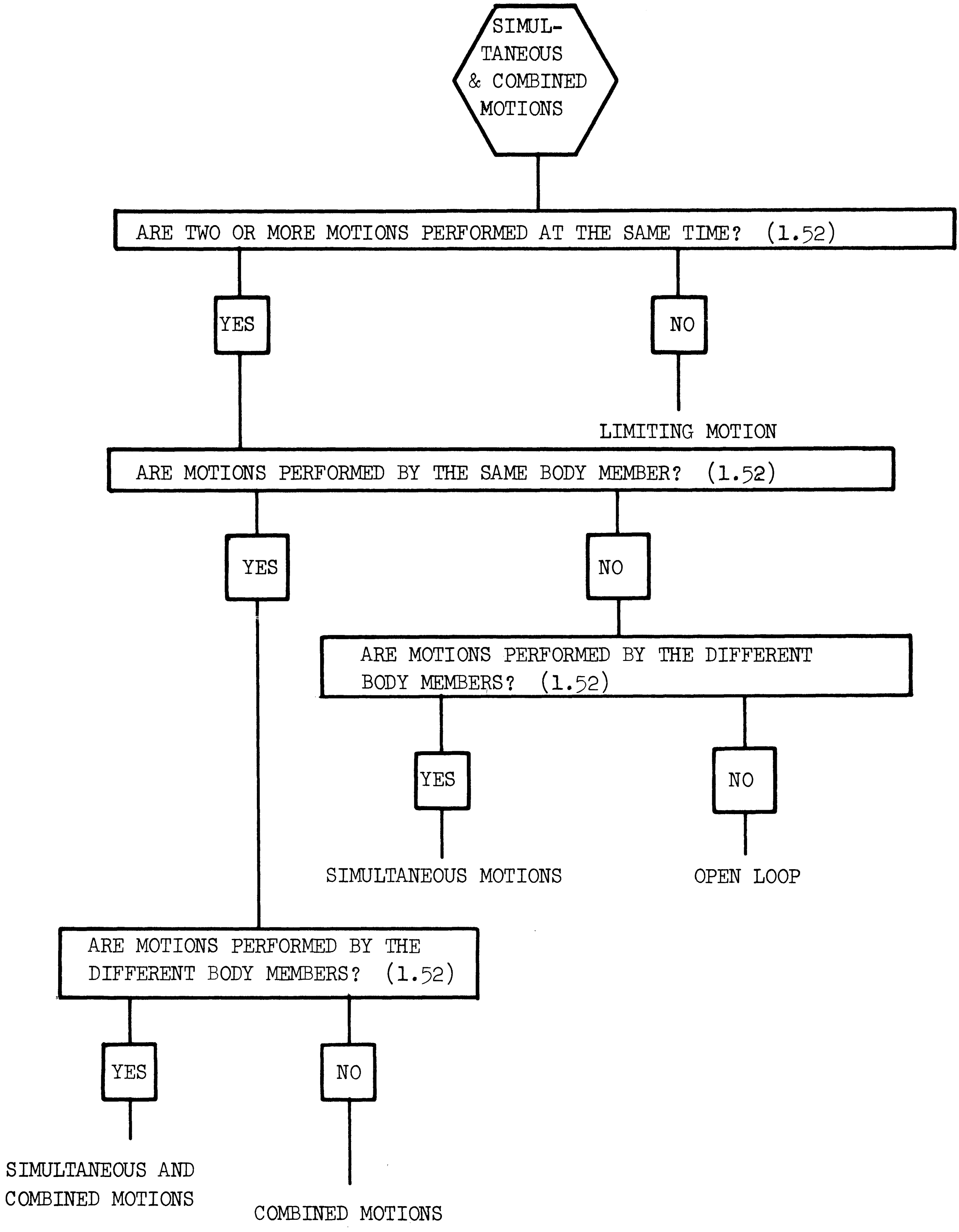


Fig. 36. Simultaneous and combined motions.

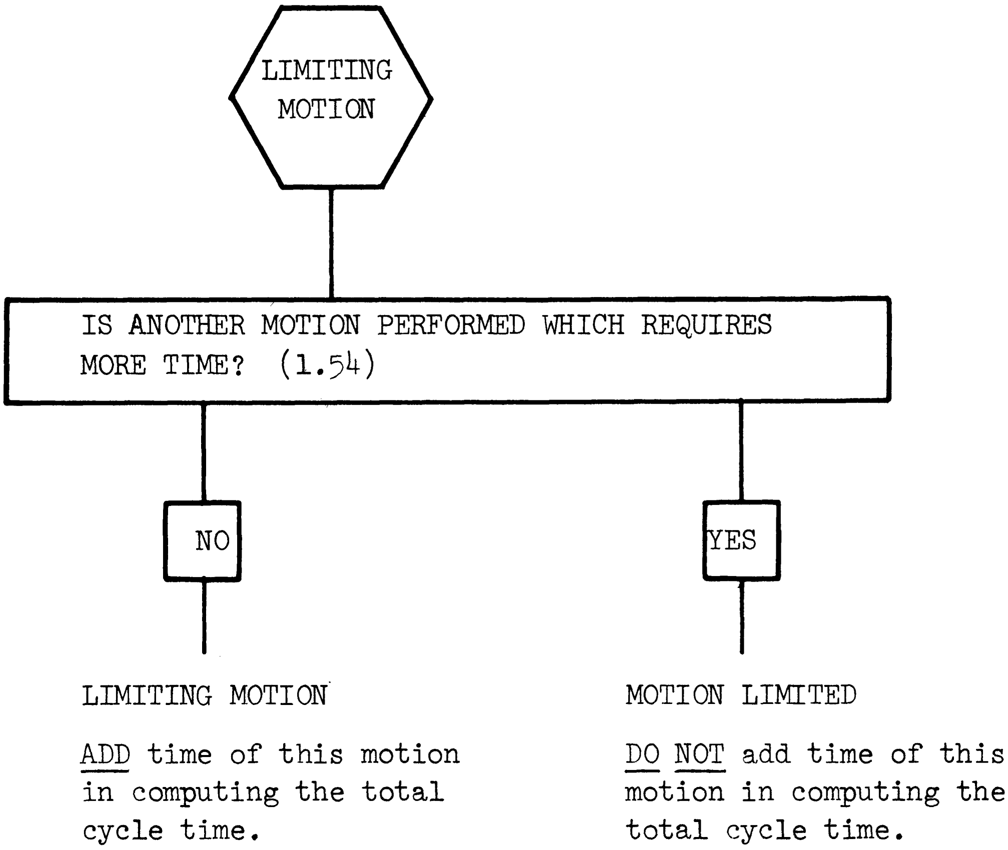


Fig. 37. Limiting motions.

CHAPTER 15

DISCUSSION

There are several kinds of errors in any predetermined time system which could result in a prediction error. In the context of this study, the potential errors due to the "quality of definitions" and open loops inherent in the system are considered most significant and an attempt is made to point out a few of the important cases so that they can be corrected.

1. The MTM motion "Grasp-G." The definition (1.02) of grasp is stated as "Grasp is the basic finger or hand element employed to secure control of an object."

   (a) The hand or finger must obtain sufficient control of the object to be able to perform the next basic motion.

   (b) The object may be a single object or a group of stacked or piled objects which can be handled as though they were a single object.

      i) Transfer Grasp - G3 (1.30). Consider the transfer of an object from one hand to another. Does this involve "securing control?" To be precise, this is actually a case of "transferring control" rather than "securing control" because the object is already under control when it is in one hand.

      ii) Regrasp - G2 (1.30) involves "shifting of control" which is once again different from "securing control."

Now if we redefine the basic motion grasp as "the basic finger or hand element employed to gain or transfer control of an object," many of the above problems will no longer exist. Here "gain of control" implies securing, increasing, or changing control.

2. Karger and Bayha (4.08) state that "sizes are denoted either in cubical limits or in diameter range for cylinders." This specification will lead to the following problem while analyzing Jumbled G4-type grasps:
   i) Consider the limits on a flat object which is either long or very short; how can the concept of cubical limits be used to analyze this situation? The question remains unanswered.
3. In case of G1C3 (1.31) and G4C (1.29) type grasps, minimum size limits have not been specified.
4. In case of Interference grasp-G1C (1.31), the concept of "nearly cylindrical object" has not been clarified.
5. In order to determine "class of fit" for "position" case analysis (1.33), there are no quantitative measures to specify "light" and "heavy" pressures.
6. In the definitions of "sit" (1.44) and "stand" (1.44), nothing has been said about the height or type (cushioned or hard) of seats.
7. The definitions of "kneel on one knee" (1.48) and "kneel on both knees" (1.50) state: "shifting one foot forward or backward." The question arises how does one specify the motion of kneeling on both knees simultaneously which does not involve any forward or backward shifting of either foot.
8. In the definition of bend (1.49), no limit has been set for hands reaching "below the level of knees."

9. In bend (1.49) and stoop motions, the definitions do not specify if the motion must start with the body from an erect standing position.

10. The method of presentation of MTM motion definitions (item 1), in general, may raise some confusion. For example, stoop is defined as "motion of lowering the body in a forward arc from a standing position, so that the hands can reach to the floor.

    (a) Stoop is performed by bowing forward at the hips and at the same time lowering the entire body by bending at the knees.

    (b) Stoop lowers the hands further than bend through a simultaneous "bend" and a knee bend." (1.48)

Comparison of part (b) raises a question as to the interpretation of "the hand can reach to the floor" in the main statement of the definition. Reasoning would indicate that stoop includes either condition while the statement of part (b) seems to be sufficient. The definition could be simplified by stating it as follows:

"Stoop is the motion of lowering the body in a forward arc while bending at the knees from a standing position, so that the hands are lowered further than the bend."

A further question can be raised about the use of the term "knee bend" a motion which is not defined by MTM. Clearly at least two difficulties can be seen. First, a motion category would appear to be missing from the MTM system and secondly the analyst is required to analyze a motion which is not defined beyond the reasonably self-explanatory meaning of the words themselves "knee bend."

CHAPTER 16

CONCLUSIONS

The specific conclusions of this report are as follows:

The decision tree approach of analyzing the MTM motions led to a critical examination of the underlying definitions and the associated "rules of thumb." In this process, the inadequacies of some of the terminologies and the resulting problems were uncovered which could now be taken up for further investigation to justify a possible change in some of the basic definitions.

While going through the analysis, it was not possible to close all the loops and hence some open loops are found to exist. Existence of an open loop indicates an incomplete decision process because there should be a rule and a table value for every possible situation or else inconsistent application may occur. These open loops indicate that the corresponding situations are not covered by the existing definitions of MTM motions.

Appendix B contains a brief description of an informal experiment that was made to see if people not familiar at all with the MTM system could use the decision trees. It was found that they were able to arrive at the correct table card values using the trees. However, with repeated use there was a tendency to "jump over" portions of the trees because of attempts to minimize decision time. In certain cases, they did reduce the time and in the others it led to a certain amount of back tracking because the subjects thought they knew more than they actually did.

In order to arrive at the correct motion by using these models, an applicator will have to go through a scientific search process very similar to the principles of computer programming. In the light of this, it can be concluded that these decision tree models will be of considerable assistance in the future in computerizing the MTM system for establishing standards.

The models give an explicit definition and the corresponding terminology for all situations and this will be of substantial help in training students in the application of MTM to industrial operations as well as in minimizing applicator error.

In these models, the most frequently occurring motions are identified first which will minimize the overall decision time.

SUGGESTIONS FOR FURTHER STUDY

The open loop areas deserve a thorough reexamination of the underlying situations.

Further study should be conducted to verify if these loops could be closed and the resulting motions identified and assigned precise time values.

These models are primarily oriented toward type 'B' industries. However, identical models can be developed to suit any other type of industry with very little reorganization.

It is too early to conclude if the models have been presented in an optimal sequence so far as their usefulness as a teaching tool is concerned. This will only be possible after considerable further research and experience in their use for instruction.

More extensive tests can be conducted to verify the exactness of these models.

APPENDIX A

A STATISTICAL APPROACH TO OPTIMIZE DECISION MODELS

Criteria - Minimum application decision time.

Let f_i = frequency of occurrence of motion type i

x_i = number of decisions required to arrive at the motions in a particular decision model, and

n = number of motion types

then $\sum_{i=1}^{n} f_i x_i$ will give a statistical measure of the relative "goodness" of the decision models. The smaller the value of the expression, the lesser will be the overall decision time and hence the better is the model.

Assuming that the value of f_i is known for a given type of industry (7), the only parameter which influences the structure of the decision model, is x_i for any given i.

As an example, Figs. 38, 39, and 40 give three alternative schematic representations of decision sequences for analyzing body, leg, and foot motions.

Table II shows the number of questions asked to arrive at a decision for a motion when using each of the three schematic layouts. The corresponding frequencies of occurrence of these motions are taken from Åberg's study (7) for industry type B. The cumulative totals of the product of number of questions (x_i) and the frequencies of occurrence (f_i) for the three cases under consideration are as follows:

Sequence No.	Cumulative Total ($\sum f_i x_i$)
1	5.46
2	6.01
3	5.08

From the above results it can be concluded that the sequence no. 3 (Fig. 40) gives the best of the alternate decision models, for body, leg, and foot motions in case of industry type 'B'.

The same principle can be extended for determining the optimum sequence of decisions for all other motions as well as other types of industries.

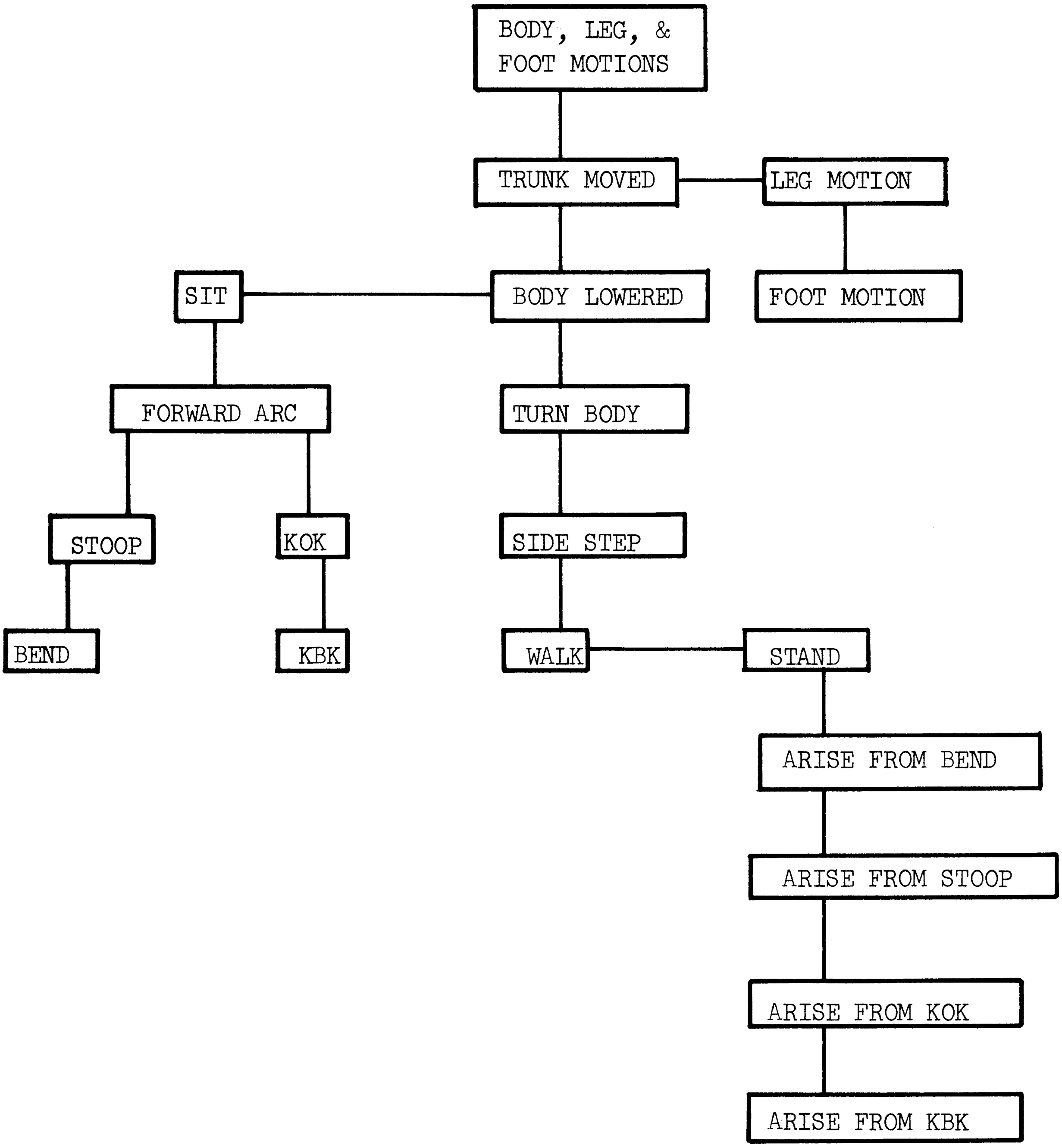


Fig. 38. Decision sequence No. 1 for classifying body, leg, and foot motions according to Åberg industry B.

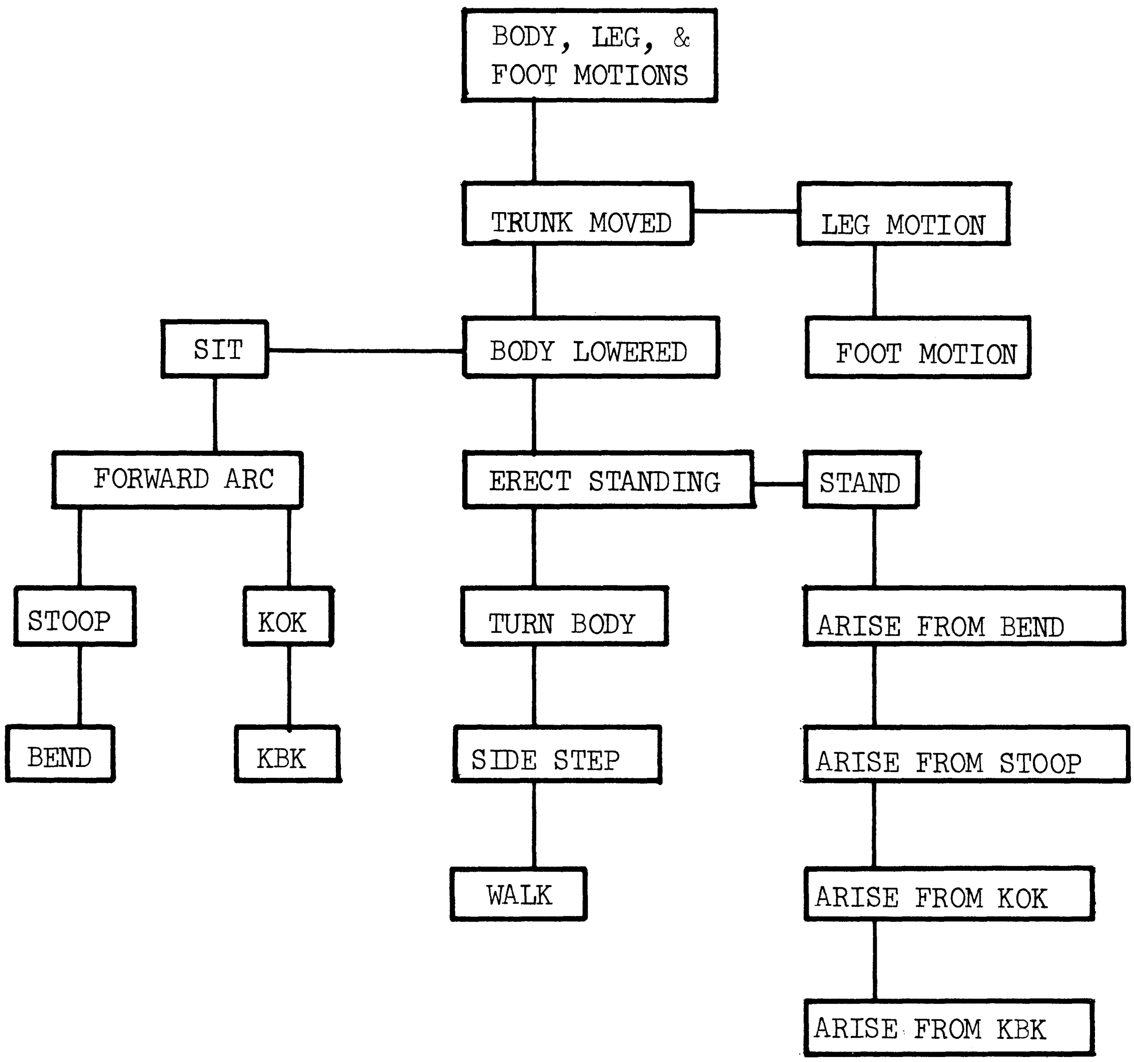


Fig. 39. Decision sequence No. 2 for classifying body, leg, and foot motions according to Åberg industry B.

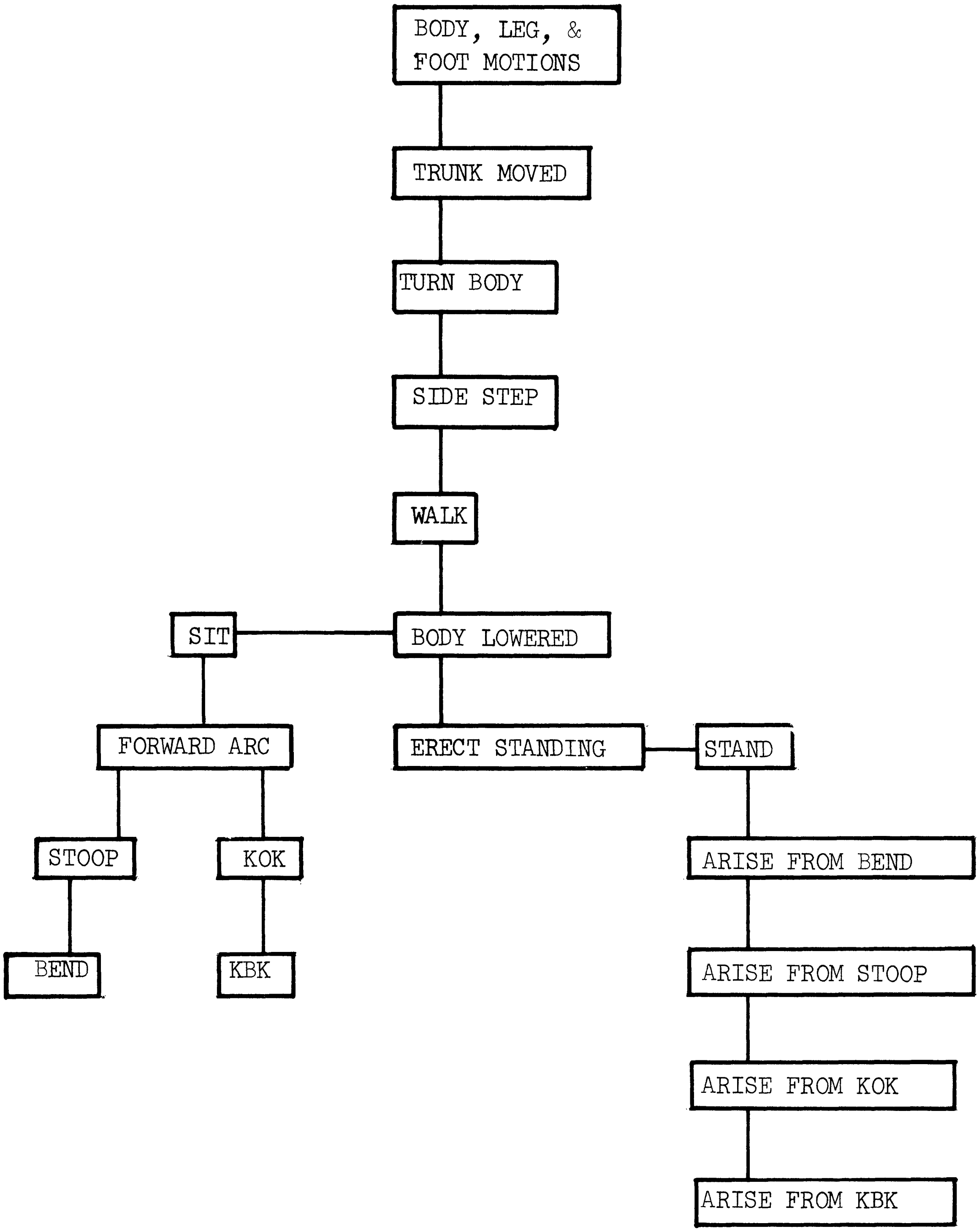


Fig. 40. Decision sequence No. 3 for classifying body, leg, and foot motions according to Åberg industry B.

TABLE II

COMPARISON OF DECISION SEQUENCE BASED ON FREQUENCY OF MOTION OCCURRENCE

Motion Type	Frequency of Occurrence as Percentage f_i	No. of Decisions x_i^*			$f_i x_i$		
		Sequence No.					
		1	2	3	1	2	3
WALK	26	6	7	5	1.56	1.82	1.30
TB	55	4	5	3	2.20	2.75	1.65
B	4	8	8	11	.32	.32	.44
S	4	7	7	10	.28	.40	.40
AB	3	8	5	9	.24	.15	.27
AS	3	9	6	10	.27	.18	.30
KOK	1	7	7	11	.07	.07	.11
KBK	1	7	7	11	.07	.07	.11
AKOK	1	10	7	11	.10	.07	.11
AKBK	1	11	8	12	.11	.08	.12
STAND	1	7	4	8	.07	.04	.08
SIT	1	4	4	7	.04	.04	.07
FM	1	4	4	4	.04	.04	.04
SS	1	5	6	4	.05	.06	.04
LM	1	4	4	4	.04	.04	.04
Cumulative Total ($\Sigma f_i x_i$)					5.46	6.01	5.08

*No. of decisions to be made to arrive at a particular motion.

APPENDIX B

TEST OF DECISION MODELS

In order to test the exactness of the decision models the following test was conducted:

SUBJECTS

Seven students (4 undergraduate and 3 graduate) who had no prior knowledge of MTM.

EQUIPMENT

MTM demonstration kit.

METHOD

The subjects were given a very thorough briefing as to what they were expected to do. They were told that the experimenter would perform a motion with the help of the 'kit' which they should observe very carefully. They would then go first through the main tree and determine the basic motion name, and secondly, go through the decision tree for the motion under consideration and determine the complete motion specification as per MTM.

Each subject separately was presented with approximately 25 different motions (one at a time) including simultaneous and body, leg, and foot motions. These motions were not presented in any specific order.

RESULTS AND CONCLUSIONS

During the course of the test some very interesting observations were made. It was observed that on many instances the subjects did not always completely follow through the decision sequence of the models. They would skip portions which they felt were not relevant to the particular motion. This tendency often led them to an open loop when they would go back and follow the sequence as per the models. All the seven subjects, however, could arrive at the correct decision whenever they carefully followed through the designed sequence.

In general, it can be concluded that the decision trees are easy to follow even for those who have no prior knowledge of MTM. However, on the basis of more elaborate test results and further research, it may be possible to design optimum models.

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1.09 Day V-9
1.10 Day III-5
1.11 Day III-5
1.12 Day III-7&8
1.13 Day III-9
1.14 Day III-11 to 13
1.15 Day IV-8
1.16 Day IV-8&9
1.17 Day IV-7
1.18 Day IV-9 to 11
1.19 Day IV-13
1.20 Day IV-12&13
1.21 Day IV-11
1.22 Day V-3
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