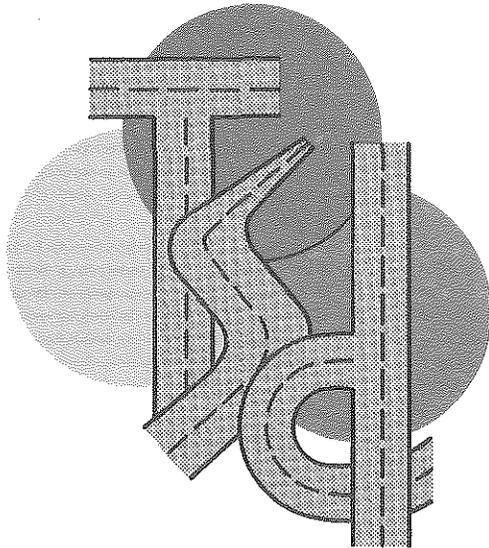


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TURNING PATH DETERMINATION PROCEDURE

A Study to Verify Predicted  
Turning Paths

TSD-G-115-69



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Prepared By

Standards Unit  
Geometrics Section  
Traffic and Safety Division

May 1969

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PREPARED BY GEOMETRICS SECTION

Traffic Geometrics Engineer . . . . . R. A. Rigotti  
Standards Engineer . . . . . J. J. Kanillopoulos  
Study Engineer . . . . . L. R. Sheets

## ACKNOWLEDGEMENTS

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## Abstract

The purpose of this study is to evaluate the method being utilized by the Geometric Standards Unit to determine turning path requirements for special vehicles. Tests were conducted at Michigan State University's parking lot to collect actual turning path information for 60- and 65-foot mobile homes. Comparisons of actual and predicted turning paths are included in this report. As a result of this study, we now have confidence in the current procedure for predicting vehicle turning paths. It is possible to determine the turning path of any size vehicle, knowing the axle spacing and required turning radius, with a high degree of accuracy.

## Introduction

The physical characteristics of vehicles, such as length, width and axle spacing, are all positive controls in designing adequate intersection radii, channelization, median crossovers and left-turn or U-turn structures. The Michigan Department of State Highways has selected the WB-50 design vehicle (50-foot wheelbase) for determining geometric requirements for these critical highway features. This design vehicle is 8.5 feet wide and 55 feet long. Detailed dimensions of this design vehicle and the 90- and 180-degree turning paths are shown in Exhibit #1.

The trucking and mobile home industries have periodically approached the Michigan State Legislature with requests to increase the length and width of trucks, trailers and mobile homes allowed on Michigan roadways. In order to properly evaluate these requests, it is necessary to be able to accurately predict the turning characteristics of these proposed vehicles for making comparisons with the WB-50 design vehicle. Vehicles having wider turning paths than the WB-50 design vehicle cannot adequately be accommodated within the boundaries of current design standards. In certain cases, encroachment on adjacent lanes by these larger vehicles is necessary and, although not usually desirable, it can be accepted if the dividing line separating two-way traffic is not crossed. In addition, on some one-lane structures such as U-turn and left-turn structures (shown on Exhibits 11-14), pavement width is not available for the increased turning requirements of these larger vehicles.

The method employed by the Geometric Standards Unit to predict the turning path of vehicles is basically a refinement of a procedure being developed by the American Trucking Association. This procedure is quite flexible, and variations in vehicle size and axle spacing can be accounted for, as well as being applicable to any degree of turn or desired radii. The American Trucking Association's procedure is an approximation which always provides a turning path larger than the actual path. Therefore, the results are ideal for design purposes because it allows for driver error and some variations between vehicle sizes. However, when trying to evaluate a request for proposed legislation, it is essential that the predicted vehicle path be as close to the actual vehicle path as possible. Appendix I describes the refined procedure that has been utilized in recent evaluations of requests for larger vehicles, such as the various 65-foot truck combinations and the increased length of mobile homes to 65 feet.

#### Problem

The procedure for predicting vehicle turning paths must be verified in order to provide confidence in the resulting comparisons made with the WB-50 design vehicle and existing highway facilities. An opportunity to gather actual turning path information became available when legislation to increase the allowable mobile home length from 60 to 65 feet was being considered by a Senate Subcommittee. At that time, the Michigan Mobile Home Association agreed to provide a 60- and a 65-foot mobile home for determining actual turning paths for these vehicles.

Experimental Technique Employed

The tests to determine actual turning paths for the 60- and 65-foot mobile homes were conducted at a large parking lot at Michigan State University. To simulate realistic controls, a typical 24-foot rural ramp terminal, with curb and gutter on the radii only, was marked in lime on the bituminous surface of this parking lot. Traffic cones were placed on the simulated curbed radii to provide vertical visibility which normally is provided by the curb face at an actual ramp terminal or urban intersection. The simulated crossroad was 24 feet wide with turning flares at the ramp terminal. This provided a 24-foot ramp opening and 24 feet of roadway width available on the crossroad to complete the 90-degree turn without crossing the center line. Exhibit #2 shows the ramp terminal layout, along with the truck and 65-foot mobile home, prior to starting the first test run. The offset in the lime markings near the right front of truck shown in Exhibit #2 represents the curb starting point. The face of curb is set back three feet from the edge of the standard 24-foot ramp roadway.

Whitewash with colored dye was used to record the movements of the test vehicles on the bituminous surface. For these tests, six critical points located on the truck and mobile home were selected for tracking. Exhibit #3 shows the six locations where plastic bottles, containing the colored whitewash, were attached to the test vehicles. Small plastic hoses connected to these bottles were taped to wooden lath near the bituminous

surface. This controlled the placement of the colored white-wash. Exhibit #4 shows the test vehicle during the first run, and three of the marking devices are visible (one at the left front wheel of truck and one at each corner of the mobile home).

Three test runs were conducted to gather actual turning path information to compare with the predicted paths. Two of the tests utilized the 65-foot mobile home and one test involved a 60-foot mobile home. The first test consisted of the long cab (10-ft. WB) and the 65-foot mobile home. In the second test, the short cab (8-ft. WB) with a 65-foot mobile home was used. The third test was conducted with the long cab (10-ft. WB) and a 60-foot mobile home.

A polar coordinate system (Exhibit #5) was established so measurements could be taken along each of the six critical paths. After the first test run was completed, it became apparent that, within the accuracy of obtainable measurements, all three axles of the mobile home tracked along the same path. Therefore, only one axle measurement for the mobile home was recorded.

A 16 mm. color motion picture and a series of color prints were taken from an elevated position to obtain adequate coverage to show vehicle placement during these three tests. A vehicle's off-tracking and turning radius cannot be determined from these pictures, but relationships between the vehicle and the simulated roadway are readily apparent.

#### Results of Experiment

Exhibits 6 through 8 are the actual and predicted turning paths superimposed to allow for a rapid and accurate comparison. Exhibits 6 and 7 indicate a favorable comparison with an error

less than one foot. This represents an error of less than 4 percent of the overall off-tracking of the truck and mobile home. On Exhibit #8, a larger error is apparent. This error resulted because the actual test path driven was a series of compound curves instead of the assumed 45-foot radius. In Exhibit #9, the predicted path was plotted using the actual left front wheel path as the reference. This latter exhibit shows the same small error as Exhibits #6 and #7.

Some of the error between the actual and predicted turning paths was caused by the poor weather conditions that existed while tests were conducted. The wind was extremely strong and blowing the whitewash as it fell from the plastic hoses to the bituminous surface. Even with the hoses as close to the pavement as possible, some lateral displacement of the whitewash occurred because of the gusty wind conditions. The high wind also caused problems in taking measurements from the center of the polar coordinate system to the critical tracks. A cloth tape was used and, to keep the tape from moving while measurements were being taken and recorded, it was necessary to hold the tape down at some intermediate points. Therefore, it is possible that the tape was not always straight, thus introducing some error in the actual measurements.

A recognized error in predicting the turning path of vehicles is that an assumed radius must be selected for the predicted path, but the driver cannot turn the steering wheel instantaneously from one setting completely to another setting, as would be required to follow the assumed vehicle path. This problem is best illustrated on Exhibit #8, where the actual

path is a series of compound curves or spiral, rather than a simple arc. The American Trucking Association's procedure provides a method to determine the minimum turning radius for different wheelbases; however, most turns are normally completed at some larger radius. Before these tests were conducted, it was assumed, on the basis of previous experience, that the turning radius would be 45 or 50 feet. The 45-foot radius was plotted first and was sufficiently accurate so the 50-foot radius was not plotted.

Since the differences between the actual and predicted turning paths are so small, it can be concluded that the method now being utilized is valid for making turning path predictions of existing or proposed large vehicles.

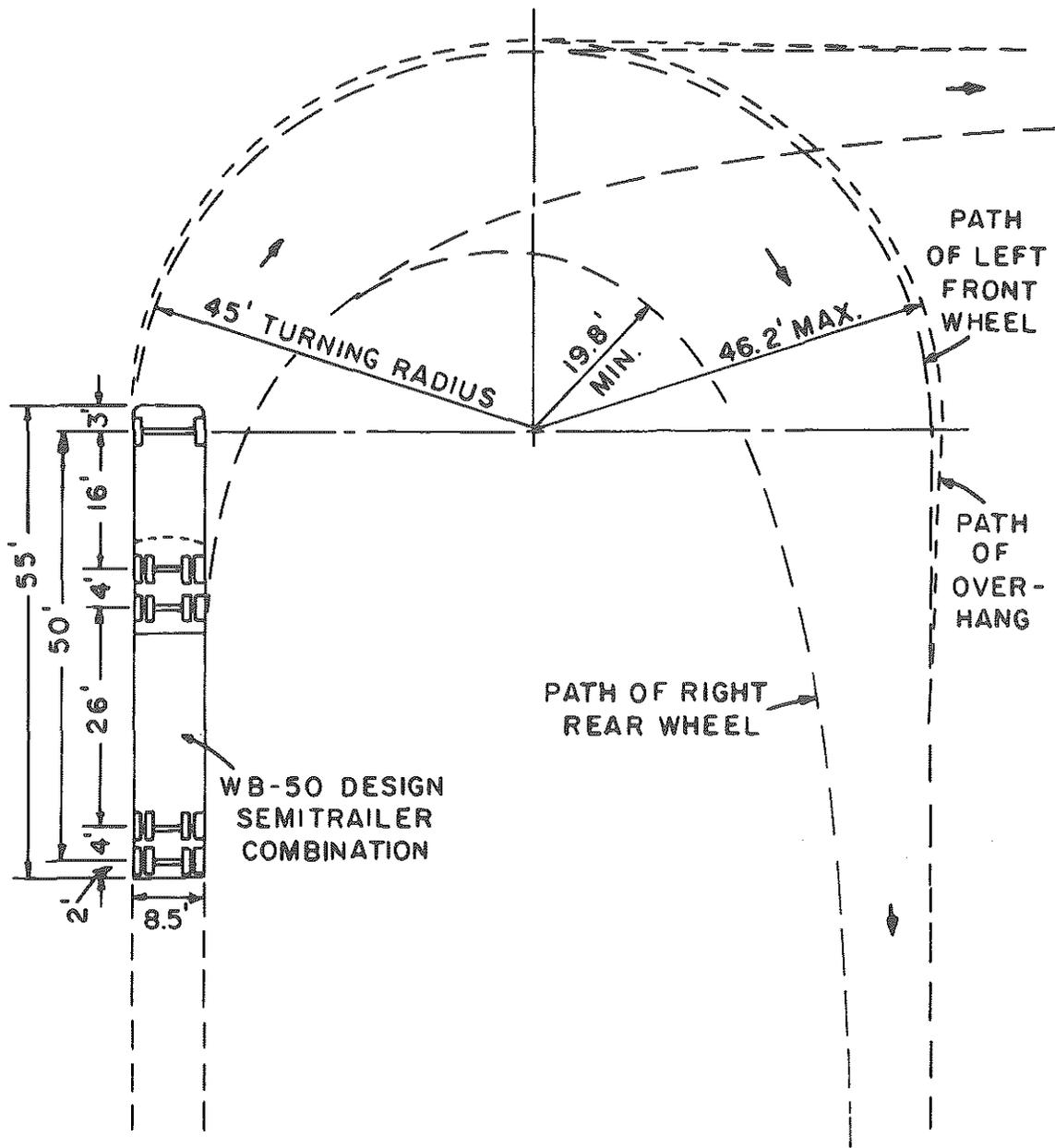
#### Application of Results

The method of determining vehicle turning paths, as shown in Appendix I, has many applications. One application is to make comparisons with the current WB-50 design vehicle's minimum turning path. Another application, which is more direct, would be to make comparisons with geometric elements of an existing highway, such as intersection radii, channelization, median crossovers and left-turn or U-turn structures which the proposed vehicle would be required to negotiate. Exhibit #10 is a typical example of how large vehicles can be accommodated on existing ramp terminals. In order for the truck and mobile home to make

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a right turn from the ramp terminal onto the crossroad without encroaching into the opposing traffic lane, the turn must begin in the center of the ramp terminal, rather than from the right-turn lane.

When comparing the 65-foot mobile home (long cab) turning requirements with the width available on the left-turn structure over I-75 at 9 Mile Road in Macomb County (Exhibits 11 and 12), it is apparent that this vehicle cannot negotiate the structure. However, the comment is frequently made that the vehicle could turn a larger radius and complete the turn. An advantage and another application of the procedure shown in Appendix I is that a larger radius turn can be predicted and then checked for adequate clearances. Exhibits #13 and #14 shows the same vehicle and structure as Exhibits #11 and #12 except that the largest possible radius is utilized. From these exhibits, note that the edge of the mobile home would be extremely close to the bridge railing. No margin for driver error is provided, so it is doubtful that any driver would try (nor would the Department allow) the 65-foot mobile home to utilize this type of structure.

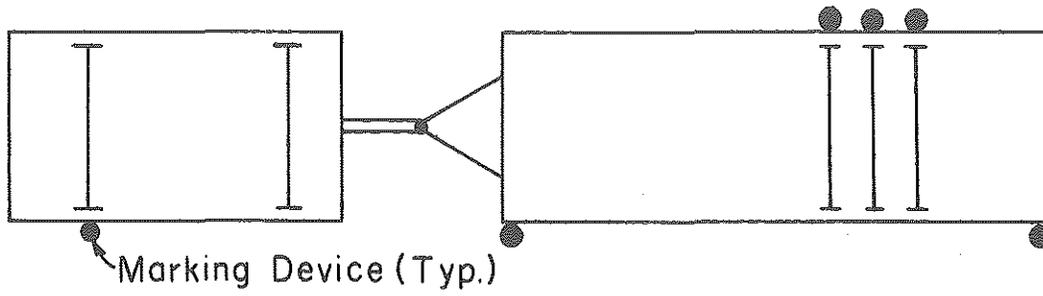


WB-50 DESIGN VEHICLE

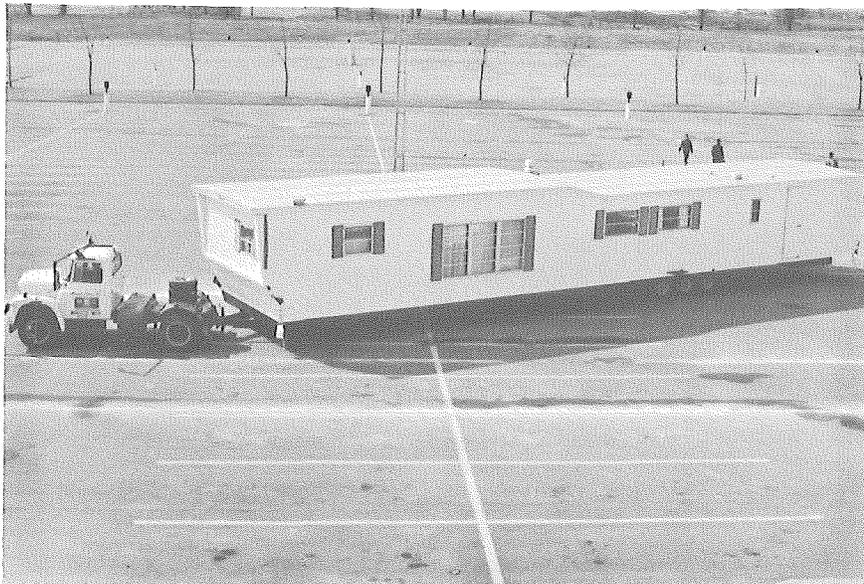
START OF FIRST TEST RUN



MARKING DEVICE LOCATIONS ON TRUCK AND MOBILE HOME

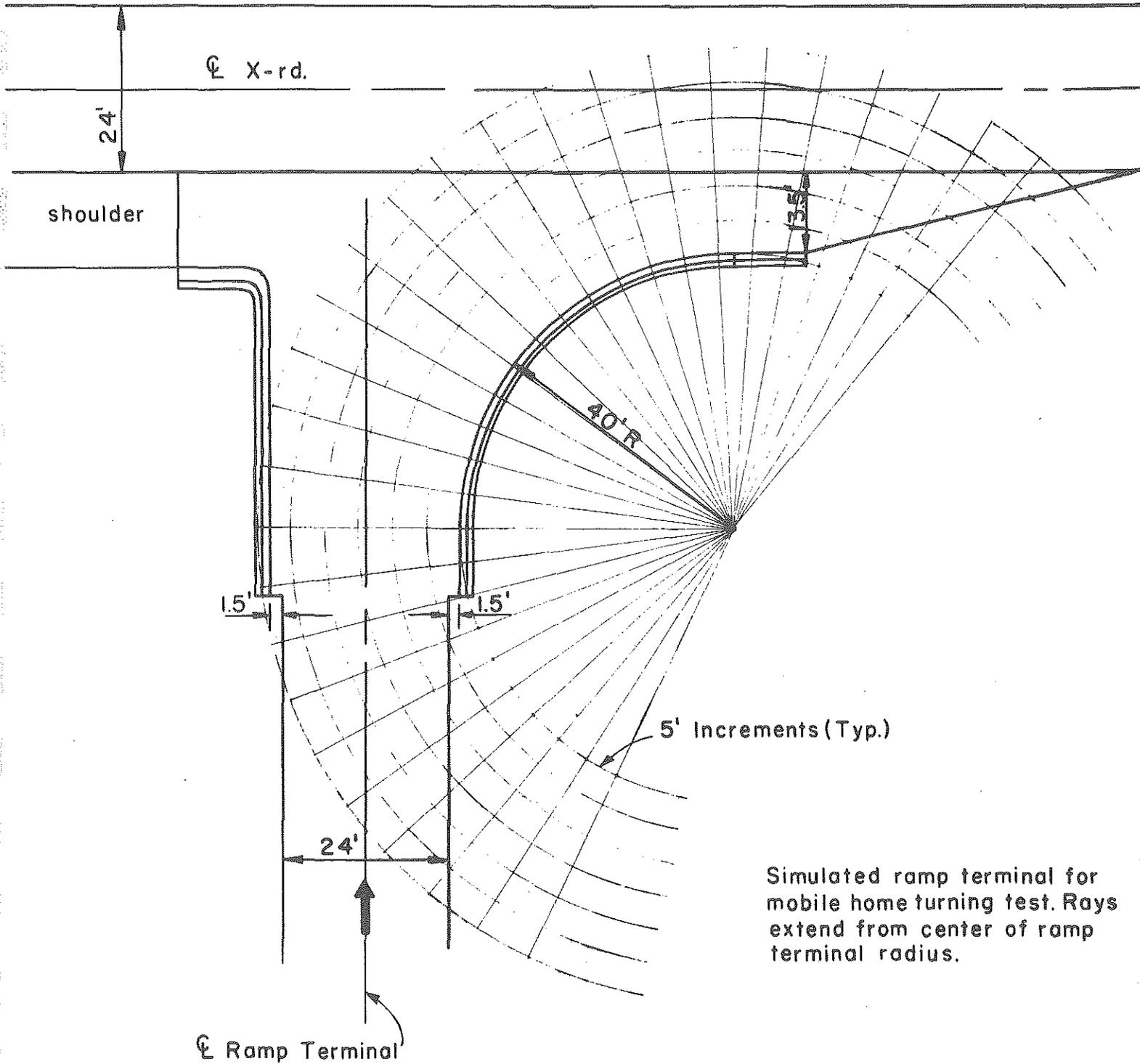


COMPLETING FIRST TEST RUN - SHOWING THREE MARKING DEVICES

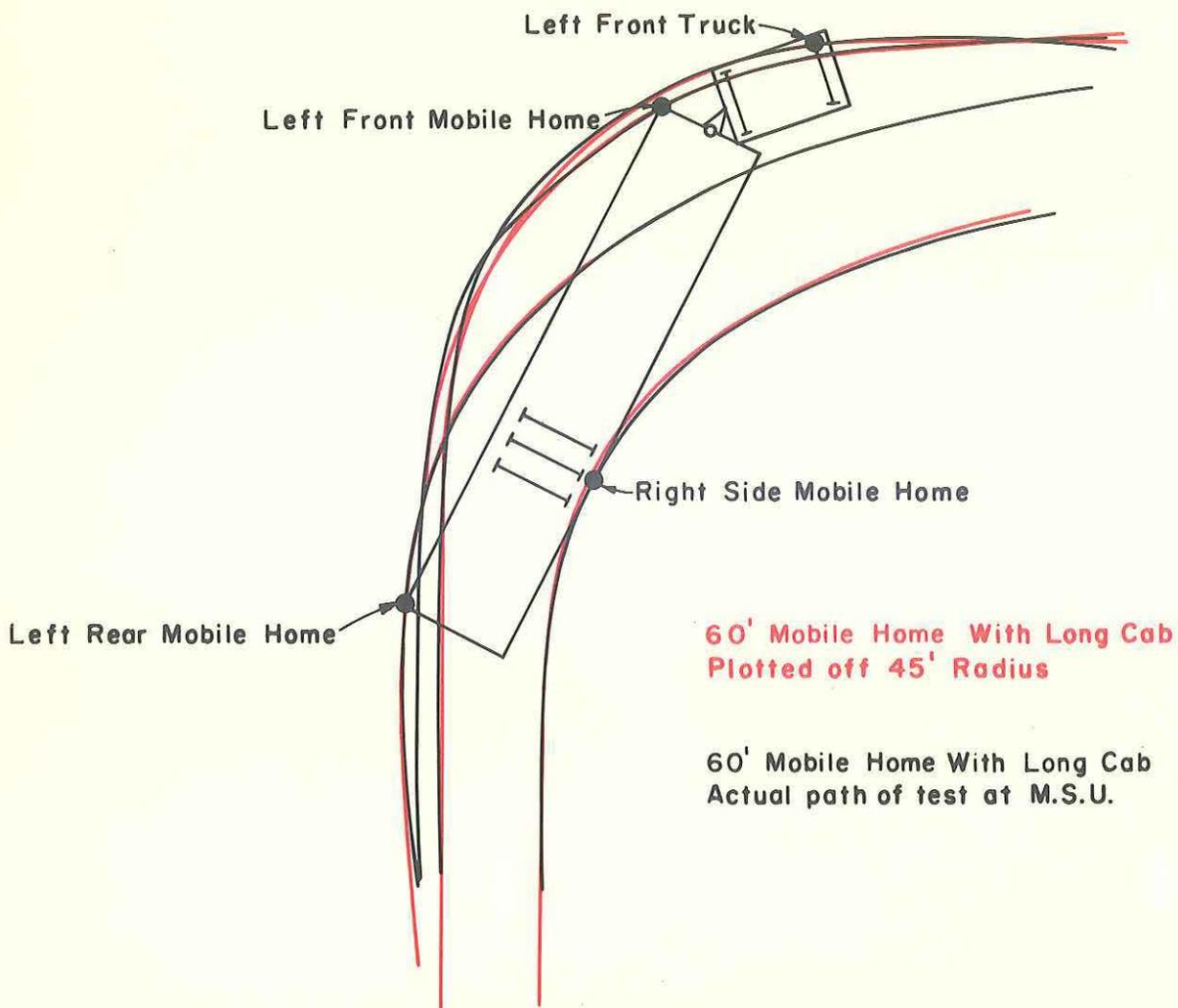


Marking devices located on left side at corners of mobile home and front of truck

# SIMULATED RAMP TERMINAL SHOWING POLAR COORDINATE SYSTEM



TURNING PATHS  
PLOTTED vs ACTUAL

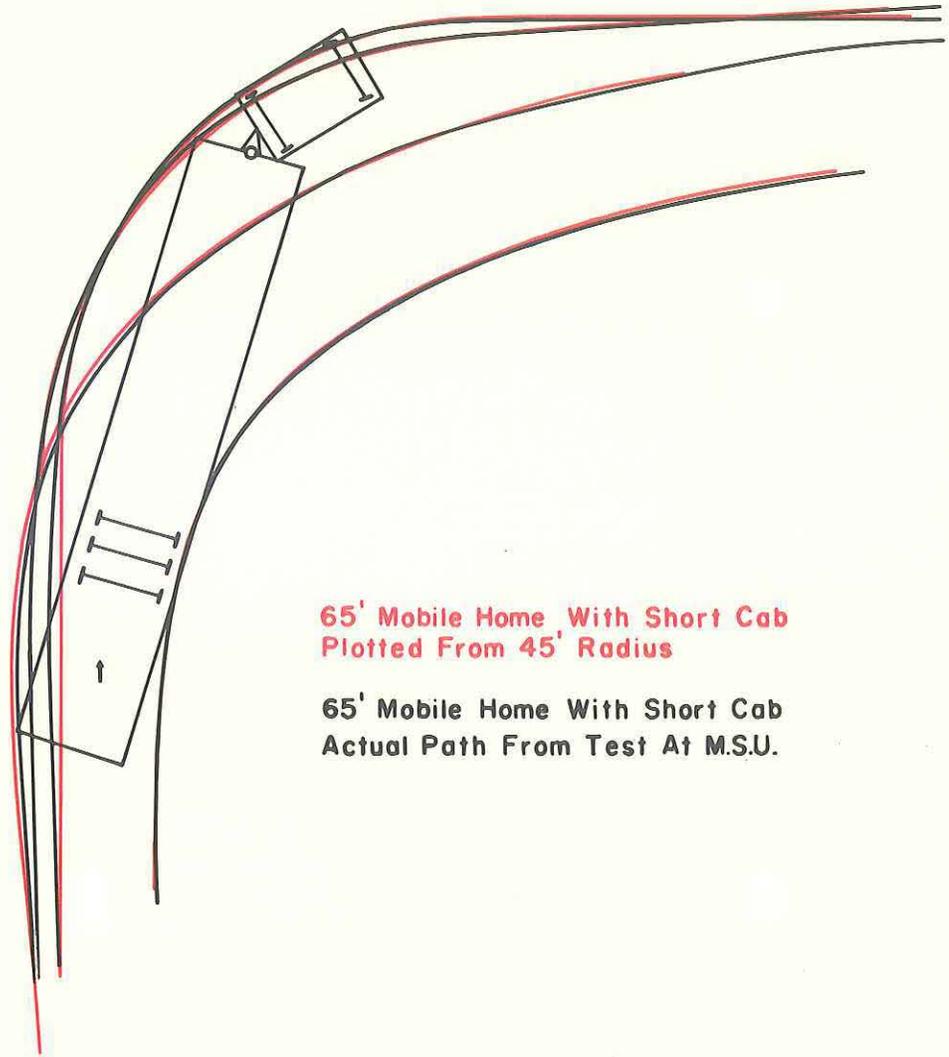


60' Mobile Home With Long Cab  
Plotted off 45' Radius

60' Mobile Home With Long Cab  
Actual path of test at M.S.U.

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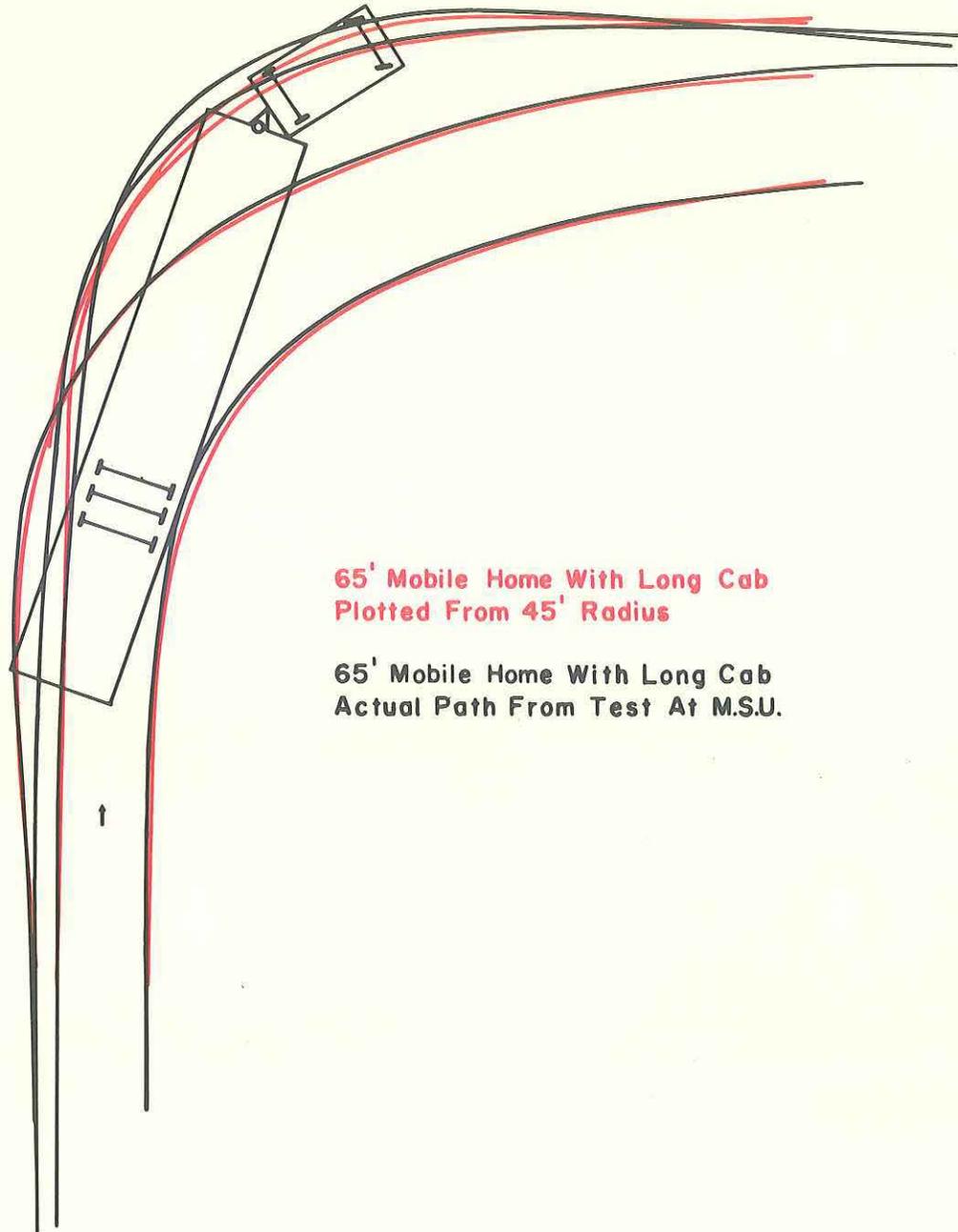
TURNING PATHS  
PLOTTED vs ACTUAL



65' Mobile Home With Short Cab  
Plotted From 45' Radius

65' Mobile Home With Short Cab  
Actual Path From Test At M.S.U.

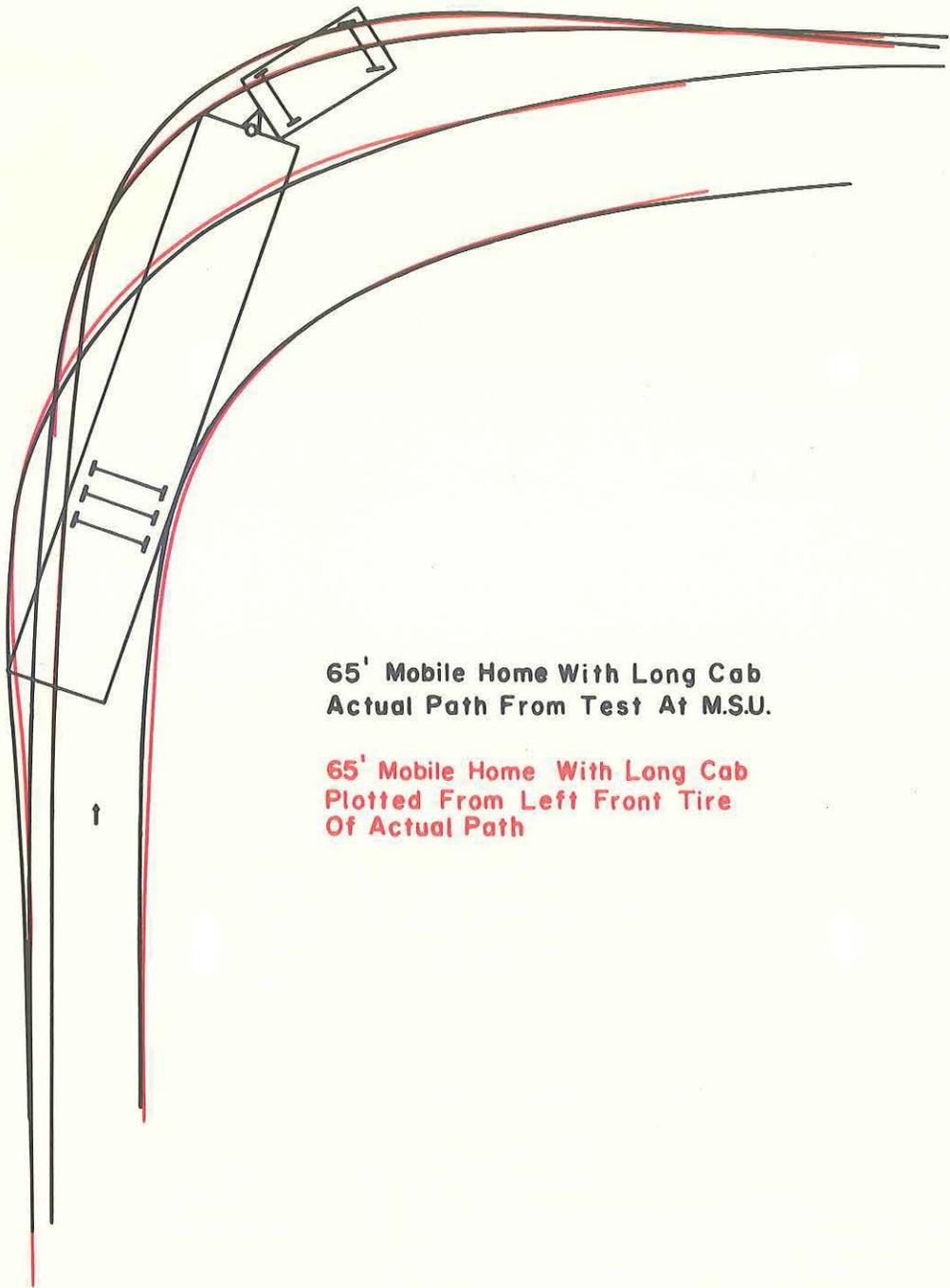
TURNING PATHS  
PLOTTED vs ACTUAL



65' Mobile Home With Long Cab  
Plotted From 45' Radius

65' Mobile Home With Long Cab  
Actual Path From Test At MSU.

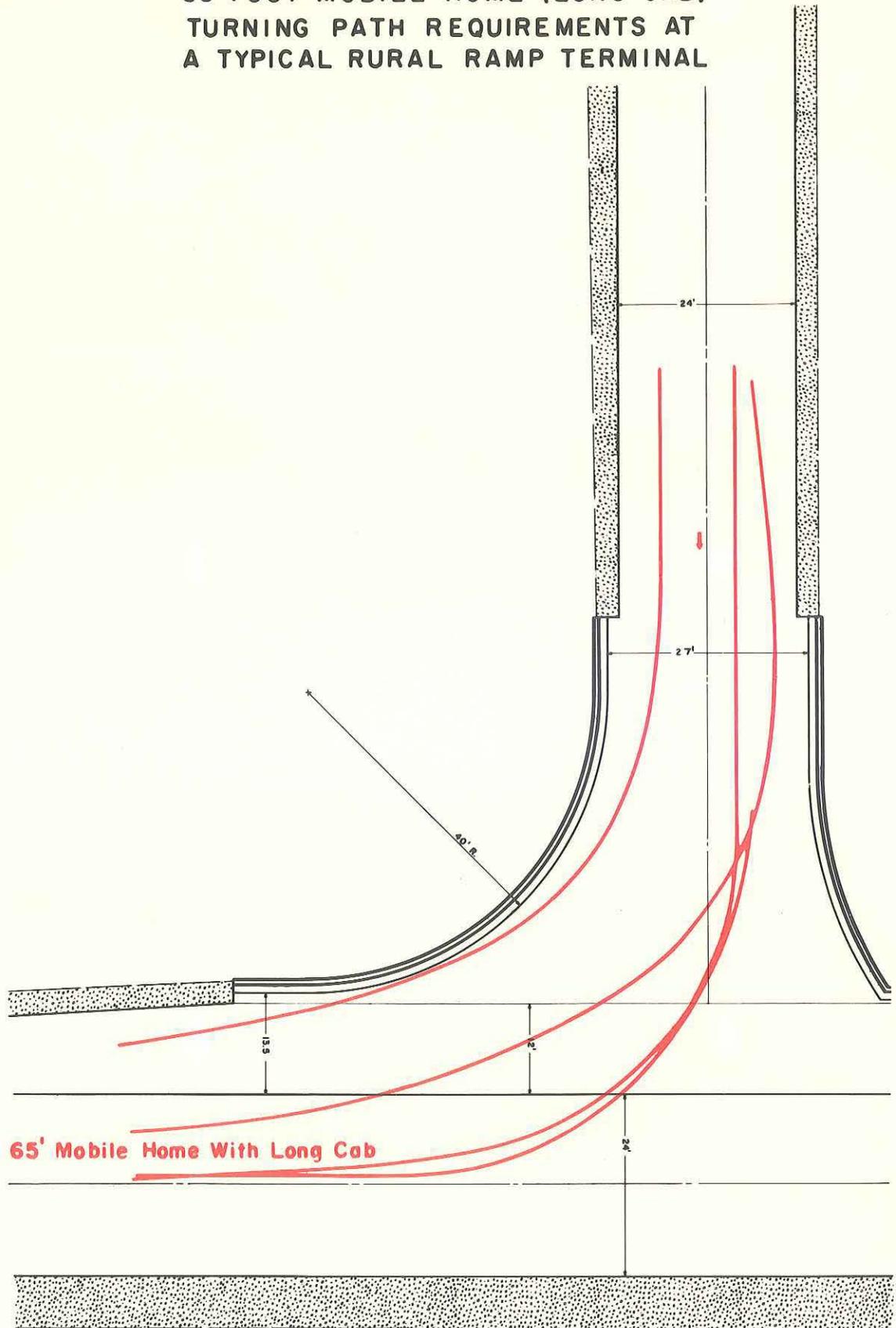
**TURNING PATHS  
PLOTTED vs ACTUAL**



**65' Mobile Home With Long Cab  
Actual Path From Test At MSU.**

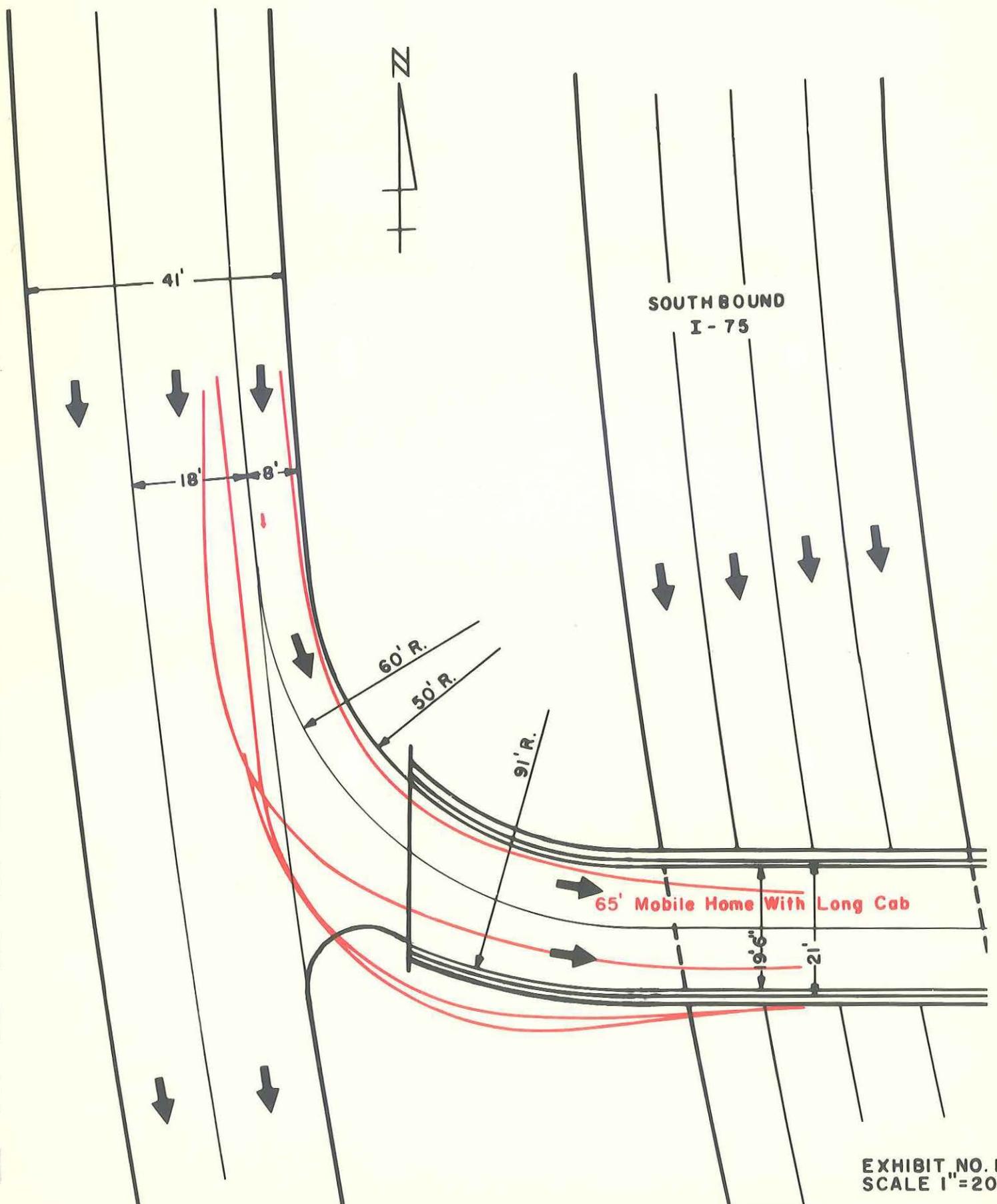
**65' Mobile Home With Long Cab  
Plotted From Left Front Tire  
Of Actual Path**

65 FOOT MOBILE HOME (LONG CAB)  
TURNING PATH REQUIREMENTS AT  
A TYPICAL RURAL RAMP TERMINAL

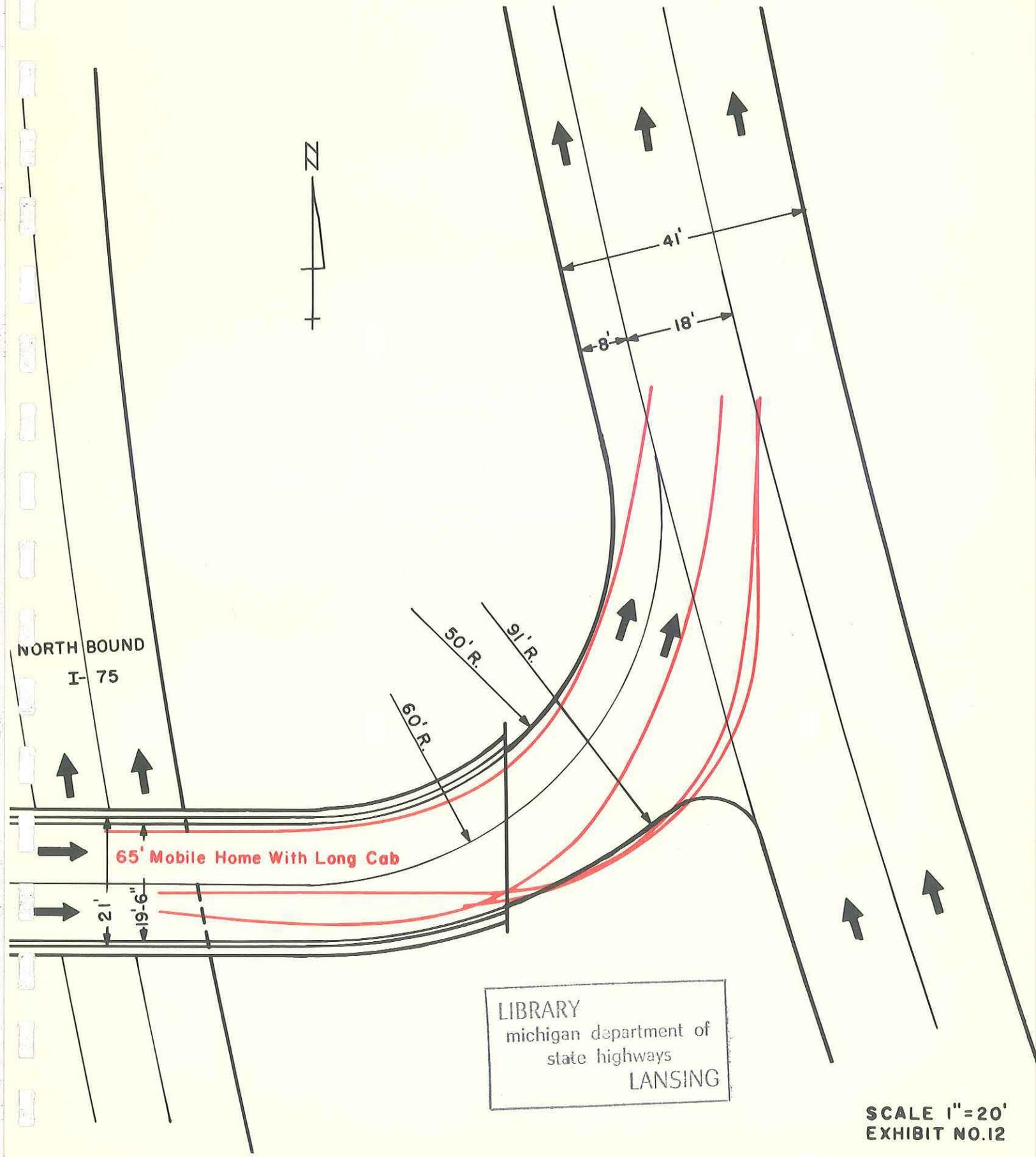


65' Mobile Home With Long Cab

65 FOOT MOBILE HOME (LONG CAB)  
TURNING PATH REQUIREMENTS WITH  
MINIMUM RADIUS AT LEFT TURN STRUCTURE,  
I-75 AT NINE MILE ROAD, MACOMB COUNTY.



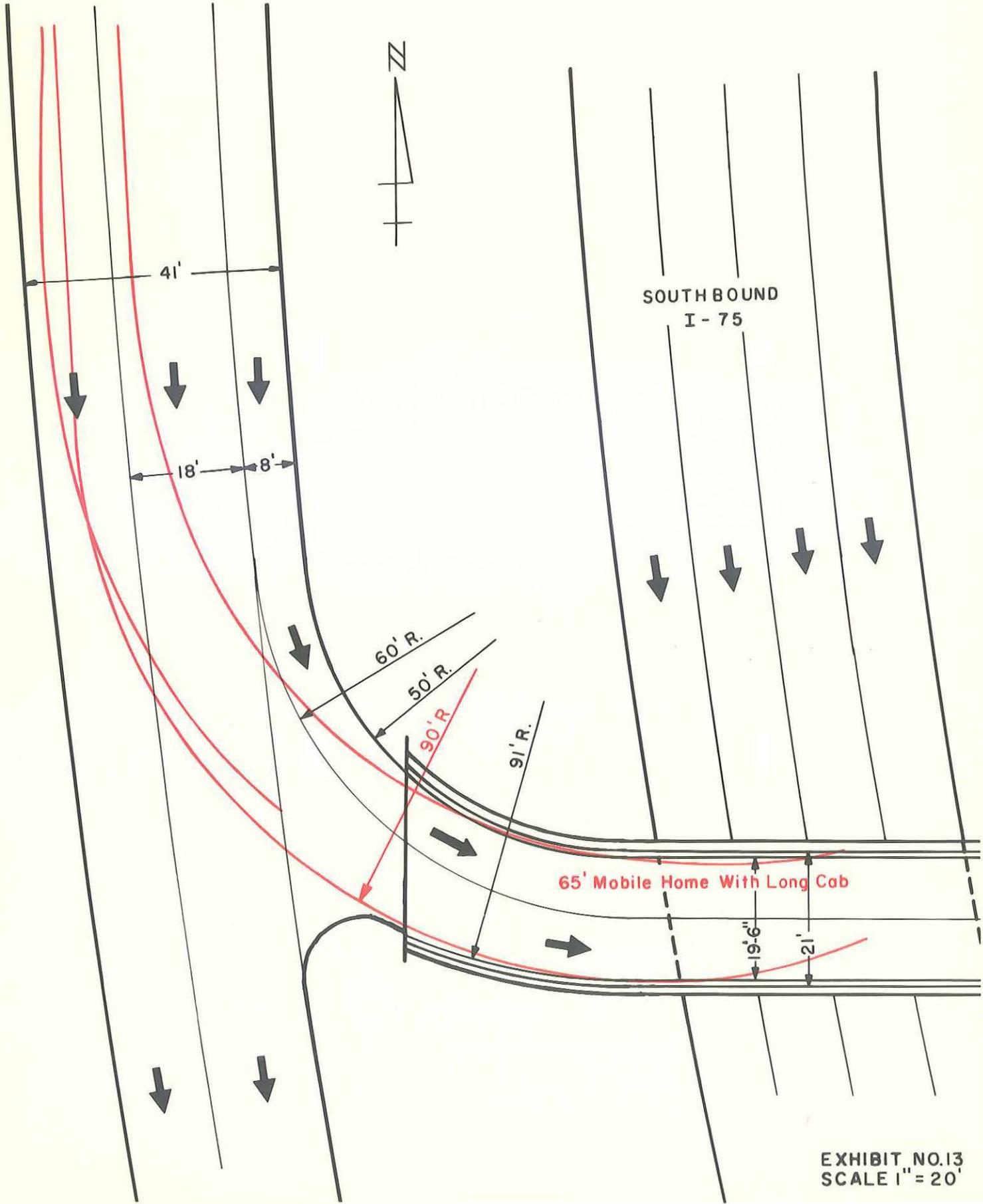
65 FOOT MOBILE HOME (LONG CAB)  
TURNING PATH REQUIREMENTS WITH  
MINIMUM RADIUS AT LEFT TURN STRUCTURE  
I-75 AT NINE MILE ROAD, MACOMB COUNTY.



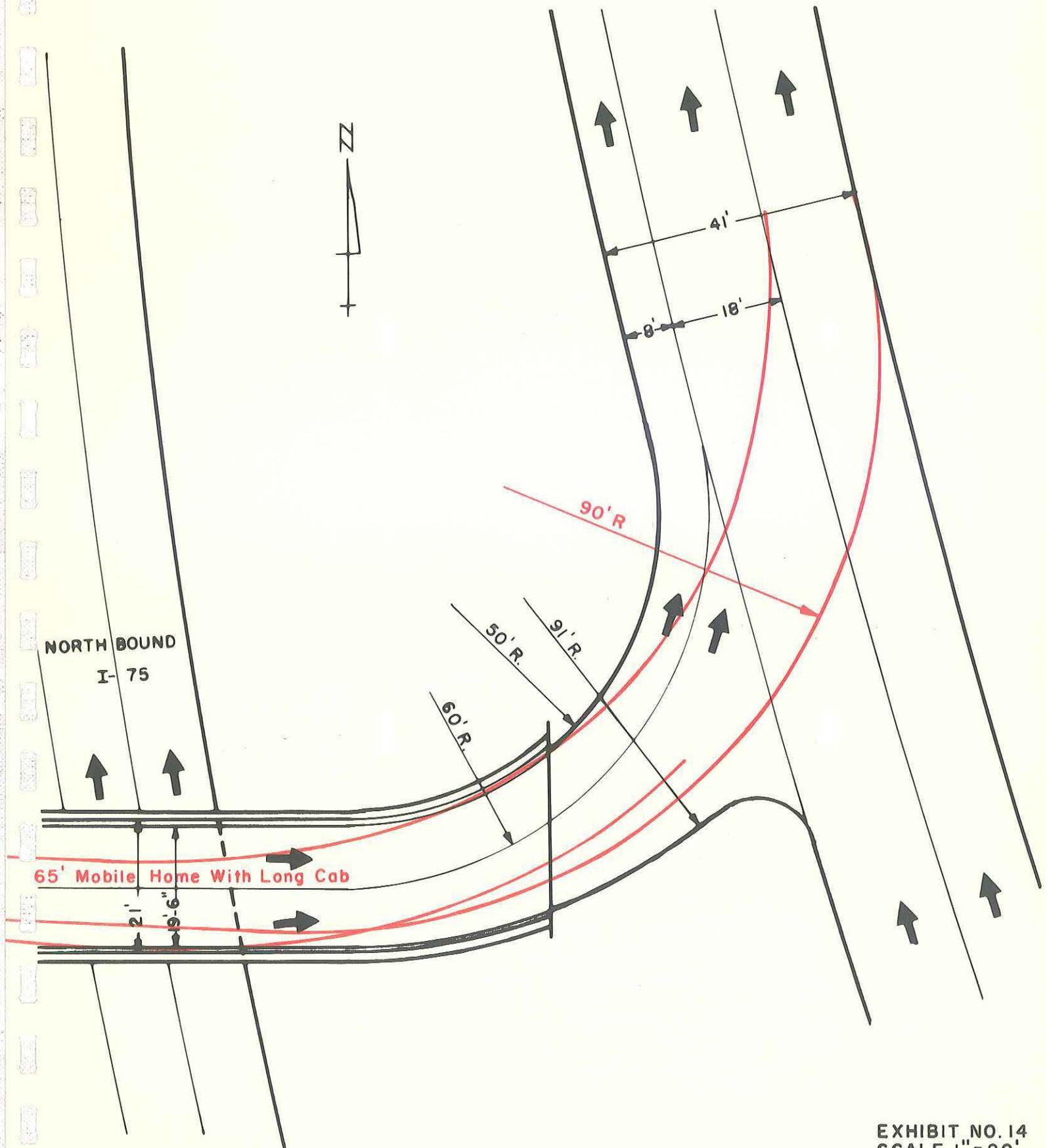
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SCALE 1"=20'  
EXHIBIT NO.12

65 FOOT MOBILE HOME (LONG CAB)  
TURNING PATH REQUIREMENTS WITH  
MAXIMUM ALLOWABLE RADIUS AT  
LEFT-TURN STRUCTURE, I-75 AT  
9 MILE ROAD, MACOMB COUNTY



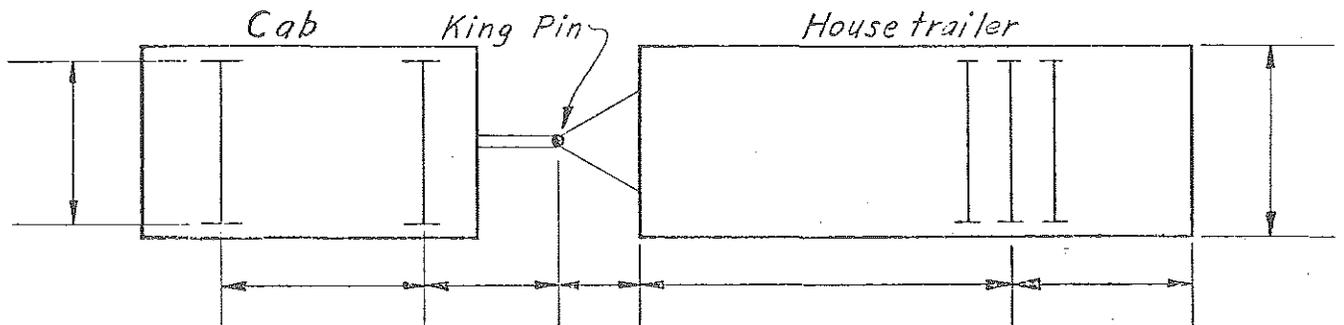
65 FOOT MOBILE HOME (LONG CAB)  
TURNING PATH REQUIREMENTS WITH  
MAXIMUM ALLOWABLE RADIUS AT  
LEFT-TURN STRUCTURE, I-75 AT  
9 MILE ROAD, MACOMB COUNTY



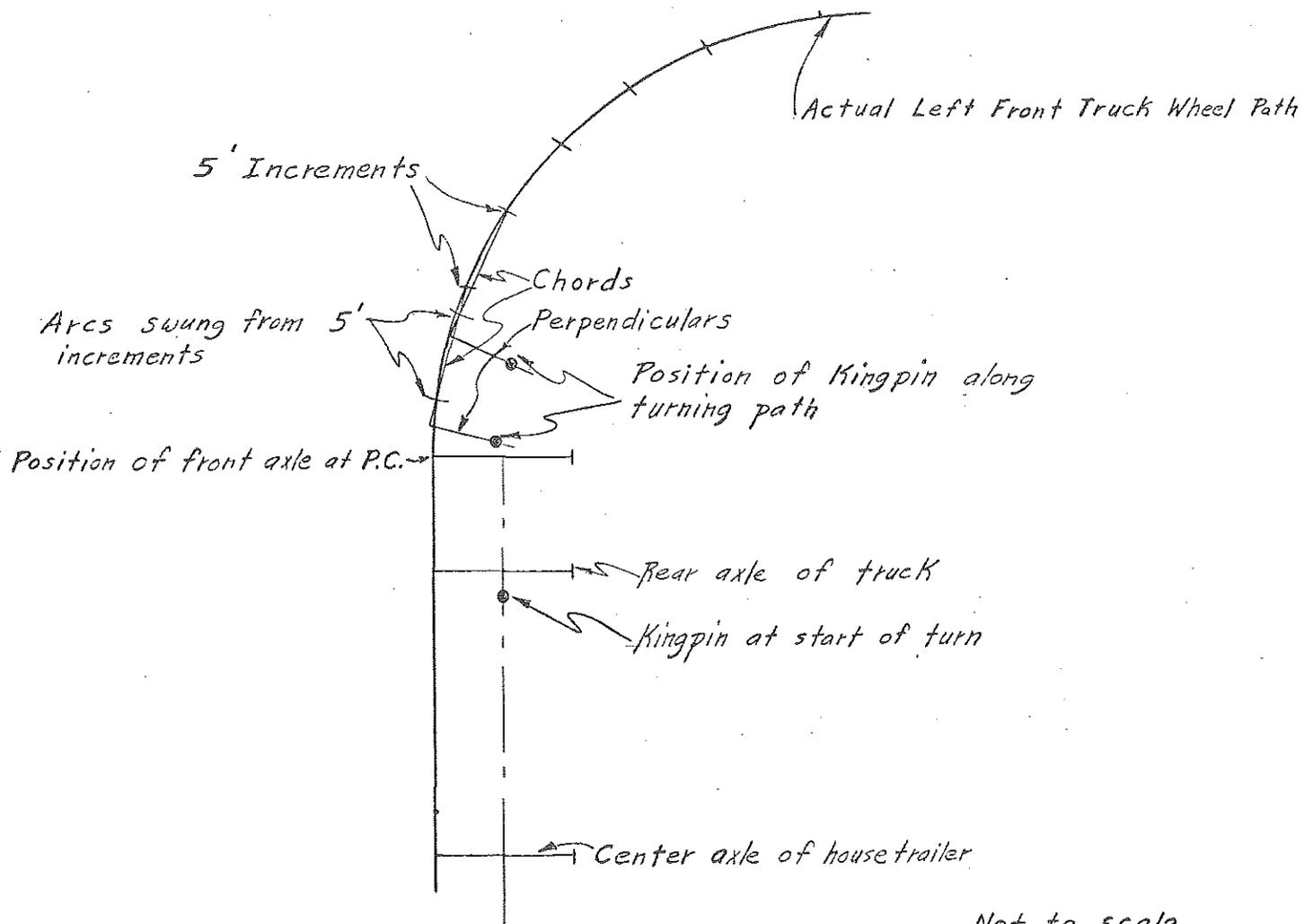
APPENDIX I

Procedure used to determine turning path  
of a housetrailer (or any other long vehicle)

1. The following dimensions of truck and housetrailer must  
be known.

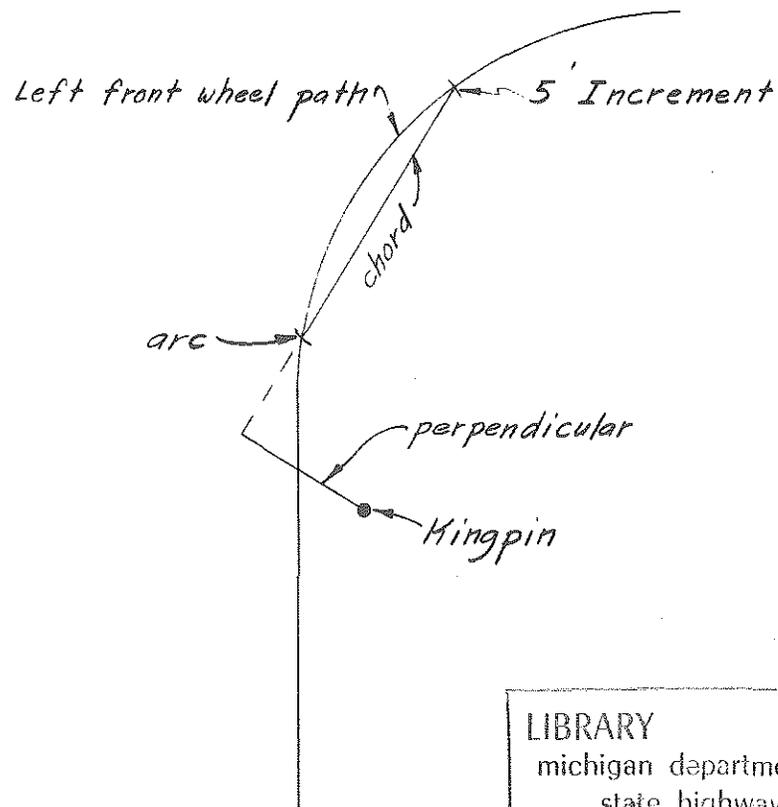


2. Plot turning path (showing radius and degree of turn) of left front truck wheel at some appropriate scale.
3. Starting at P.C. of this wheel path, plot 5' increments around path. Locating front axle of truck at P.C., draw to scale rear axle of truck, kingpin, and center axle of rear of house trailer. Draw perpendicular line thru axles and kingpin.



Not to scale

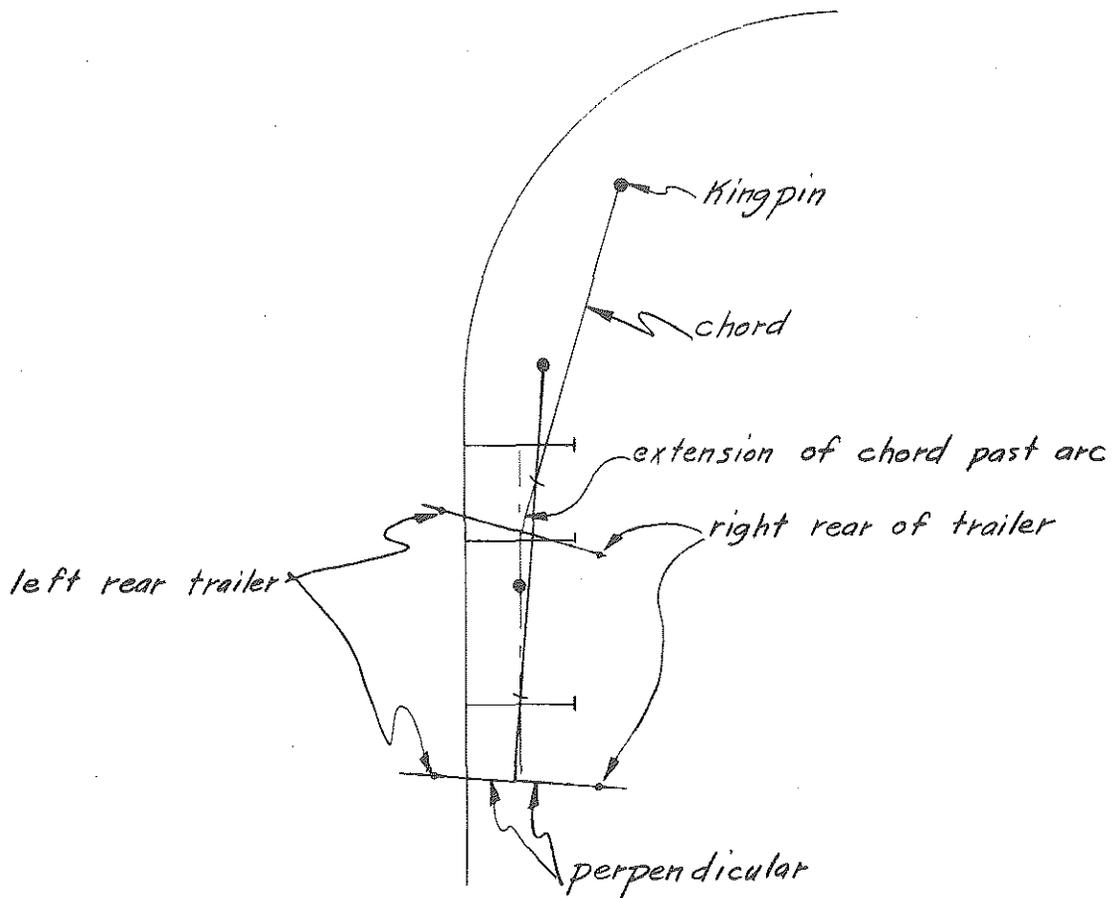
- Starting at first 5' increment, swing arc across wheel path equal to wheelbase of truck. Connect these two points with chord, extending chord so that total length equals distance from front axle of truck to kingpin.



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Draw a line perpendicular to end of the extended chord. Measure on this perpendicular line a distance equal to 1/2 the axle length. This point is the first position of kingpin. Continue this procedure until kingpin path is plotted.

5. Set beam compass equal to distance from kingpin to center axle of rear of trailer. Starting at first plot of kingpin, swing an arc that crosses center line thru axles and kingpin. Connect these two points with chord. Extend the chord a distance such that entire length equals house-trailer length. Draw a line perpendicular at end of the extended chord. Measure in both directions on the perpendicular line 1/2 width of trailer. These two points represent left rear and right rear of trailer. Continue this procedure for each kingpin plot.



6. To plot left front trailer path, measure distance from kingpin to front of trailer along previously constructed chord. From this point, draw a line perpendicular and measure half the width of trailer. This represents a point on the left front trailer path. Continue procedure until path is plotted.

