



**Research Report  
KTC-96-8**

**A PROPOSED METHOD OF CALIBRATION AND  
CORRELATION OF WEIGH-IN-MOTION SYSTEMS**

by

David L. Allen  
Transportation Engineer V

and

Jerry G. Pigman  
Transportation Engineer V

Kentucky Transportation Center  
College of Engineering  
University of Kentucky  
Lexington, Kentucky

in cooperation with

Kentucky Transportation Cabinet  
Commonwealth of Kentucky

and

The Federal Highway Administration  
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16. Abstract There are various types of weigh-in-motion systems currently in use by agencies that collect weight data. These include load cells, bending plate, capacitance pads, piezoelectric cables, and bridge WIM's. The response and behavior of these systems differs from one type to another. Most states calibrate these systems by one of two methods. The first is to calibrate by running a truck or trucks of known weights across the scales a number of times. The second is to use a sample of trucks from the traffic stream. This report details a field calibration and correlation test site between a slow-speed WIM at a permanent weigh station and five other WIM systems. These other systems were a capacitance pad, a piezoelectric cable installed in a rigid slab, a piezoelectric cable installed in a flexible pavement, a bridge WIM installed on a simple span, and a bridge WIM installed on a continuous span. From this test site, a method of calibrating WIM systems was developed that uses the accumulative distribution functions of the vehicle gross weights from the traffic stream. By developing a distribution function for a standard scale (in this case, the permanent weigh station) and also for the WIM system being calibrated, a continuous calibration function can be developed between the two systems. Any weights obtained by the calibrated scale in the future can then be corrected to the standard scale by application of the continuous calibration function. This report details a recommended calibration procedure for correlating all scales in the state by use of calibration distribution functions. A computer program ("WIMBOTH") was developed to calculate the distribution functions and the calibration functions.					
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## 1.0 INTRODUCTION

For many years, weight data from permanent weigh stations were used to estimate equivalent single axleloads (ESAL's). However, this did not provide a sufficient amount of data because weigh stations were costly to build and caused considerable disruption to truck traffic. Increasingly, permanent and portable weigh-in-motion (WIM) scales have provided the bulk of weight data that are available to the traffic estimator.

WIM scales were first used in Kentucky in 1988. Various types of WIM scales are currently in use in Kentucky. These types include bending plate, portable capacitance pads, bridge WIM's, and piezoelectric cables.

Accurate axleload or weight data are essential in developing ESAL estimates or forecasts. To provide accurate weight data, it is necessary to properly calibrate WIM scales. However, calibration of the various types of WIM systems can be difficult because these systems will respond differently to the dynamic forces of moving traffic and provide weights that are different from those that are provided by static scales. Also, responses to dynamic loads vary from one type of WIM system to another. Awareness of this variability of response raises concern that ESAL's estimated using the data from one scale may not be the same as estimates made from a different scale or system. Furthermore, are these systems subject to "drift" in calibration?

It appears a system of calibration is necessary that will provide calibration of all WIM systems that are in use in Kentucky to a standard scale, and in addition, will provide a means to check each individual scale for drift.

## 2.0 OBJECTIVES

The information, analyses, and recommendations given in this report are part of a larger study entitled "*Calibration and Correlation of Weigh-in-Motion (WIM) Systems and ESAL Program Enhancements*" (KYHPR-94-159). The objectives of that study were:

1. To correlate the responses of various weigh-in-motion systems currently used in Kentucky,

2. To provide a methodology for continuous correlation and calibration of the various weigh-in-motion systems used in Kentucky to ensure consistent and comparable results between each system,
3. To modify the current ESAL calculation procedures to provide more definitive and accurate methods for reflecting the effects of coal movement and a more flexible approach to accommodate evolving needs, and
4. To incorporate the current programs into a more efficient and streamlined procedure.

The last two objectives were addressed in two reports (1, 2) previously published during this study entitled "*Development of an Alternate Methodology for Identifying Heavy / Coal Trucks and Calculating ESAL'S / Axle and Axles / Truck*" (KTC-95-7) and "*Equivalent Single Axleload Computer Program Enhancements*" (KTC-95-7).

This report addresses Objectives 1 and 2 above, which are a part of Task C and a portion of Task D of the work plan.

## **3.0 BACKGROUND**

### **3.1 Factors Affecting WIM Accuracy and Performance**

A review of a paper by Lee (3) and other literature (4, 5) indicates that there are a large array of factors that can affect the accuracy of a particular WIM system. Firstly, there are factors relating to the vehicle itself. These include the gross weight of the vehicle and how accurately the scale weighs (calibration) at that particular weight. The distribution of the weight on a particular vehicle, the vehicle suspension, the type of tires, and aerodynamic forces on the vehicle all can affect the way in which the scale weighs or reacts to the vehicle load.

Roadway factors also affect the scale's accuracy. An alignment that is not level will shift weight from one axle to another. Superelevation will also cause vehicle weight to shift from one set of tires to a set on the opposite side of the vehicle. Road roughness can produce "bouncing" of the vehicle making the vehicle weigh heavy or light.

Environmental factors may produce significant changes in the way a system weighs a vehicle. Most systems are temperature compensated by the manufacturer; however, other factors such as ice, snow or wind can affect performance.

Characteristics of the WIM system itself can also affect the accuracy of weights. The location of the force sensor, the stiffness of the sensor, and the internal oscillation and internal damping of the sensor are critical to the accuracy of the system. The sensitivity of the system to the direction of the applied force, electrical sensitivity and linearity of the system, durability of the sensing elements, internal electrical stability, and tire contact area are all critical to the WIM system performance.

Interpretation of the electrical signal received from the sensing element is very important in system response and accuracy. The process that is used to convert the analog signal to a digital signal is significant. The type and response of signal filters, the process of signal averaging and integration to get total force, and the method of peak signal detection are all very important to the system accuracy.

How the weighing device is used is an additional factor in system response and performance. Does the device weigh the entire vehicle at one time, or is it used to weigh only one or two axles at a time? As mentioned earlier, is the scale on a level surface? Does the scale weigh vehicles at slow speeds or fast speeds? The internal inertial forces of the system may produce different readings depending on whether the vehicle is weighed at low or high speeds.

Lastly, the method the user employs to calibrate the system may also affect the accuracy of the scale.

### **3.2 Types of Errors in WIM Systems**

There are two types of errors that can occur in WIM measurements. One is systematic error, and the other is random error. Both can be associated with inaccuracies in internal measurement or static-to-dynamic weight differences due to external highway forces. These two types of errors are illustrated in Figure 1 and are defined by Davies and Sommerville (6) as follows.

*“The systematic error is given by the mean of the error distribution for individual measurements, whereas the random error is measured by its*

*standard deviation. Systematic errors can arise for reasons relating to the design, installation, or operation of the system and cause a repeatable bias in all measurements carried out at a particular time. Random errors, however, are uncontrollable and unpredictable, and are intrinsic to any measurement. The purpose for calibration is to compensate for systematic errors, reducing them as far as possible. The initial calibration may change over time, producing a varying systematic bias in the load measurements.”*

### **3.3 Calibration Procedures for WIM Systems**

There are two philosophies or schools of thought when considering WIM weights. One is that WIM weights should not be compared to a static weight that is used as a standard, because what the pavement actually “feels” is the dynamic weight of the passing vehicle. The other way of thinking is that the static weight should be used as the standard and any difference between the static and WIM weight is considered an “error”. It appears that most agencies that use WIM scales have chosen to follow the latter philosophy. Therefore, most WIM calibration techniques involve comparing weight reported by WIM systems to a known static weight and attempting to reduce the differences between the two to a minimum. Some researchers and agencies (5, 6) report these differences as absolute difference (AD) and others report the difference as percent difference (PD)

From the authors’ conversations with personnel from various states (Arkansas, Indiana, Minnesota, Virginia, Connecticut, Idaho, and FHWA) and from the literature (Izadmehr and Lee [7], Zuieback et. Al. [8], and Terhune [9]), it appears that most calibration is performed in one of two ways. The first is to record the WIM weight from repeated passes of a single vehicle of known weight, as determined from a static scale. The second method is to weigh selected vehicles (usually Type 9) from the traffic stream that have also been weighed on an adjacent static scale.

The recommended sample size necessary to statistically calibrate a WIM scale also has been reported in the literature. Ardeshir et. Al. (10) reporting on the I-95 Multi-state Traffic Monitoring Project indicated that they needed a random sample size of 384 observations for an accuracy of 1.0 percent at a 95 percent confidence level. Davies and Sommerville (6) used a sample size of 400 observations. Deacon (11) recommended a random sample size of 500. When using a single vehicle for calibration, the number of passes required for 1.0

percent error at a 95 percent confidence level has been reported by Zuieback et. al. (12) and Whittemore et. al. (13) to be 31.

Terhune (9) has reported that when only one vehicle is used in calibration the assumption is made that the relationship between sensor inputs and actual weights is linear and that the relationship holds for the entire range of weights being measured, as well as for speeds, temperature, and vehicle types. However, Hamrick and Fugit (14) have reported that the weight relationship is not linear and have used a multiple calibration factor method for calibration. Niekerk and Visser (15) report that vehicle configuration (type) is important and should be "accounted for" in calibration. In addition, Niekerk and Visser (15) and Sebaaly and Tabatabaee (16) have reported on the significant effects of vehicle speed on calibration.

Zuieback et. al. (12) have published a procedure where pavement roughness is considered in WIM calibration methodologies. Black (17) has reported that increasing roadway roughness produced a corresponding increase in random differences of truck weights at four WIM sites where piezoelectric cables were used.

At permanent WIM sites, Quinley (18) has indicated "*that the traffic patterns, and particularly the truck operating characteristics, are very repetitious*". Other researchers, including Dahlin and Novak (19) also have noted this fact. This repetition of traffic pattern at a WIM site is often used to assist in determining when the scale is drifting out of calibration or there are changing pavement conditions. Figure 2 (from Reference 19) shows that on January 18, 1992 the distribution of vehicle weights is dramatically different from those of the remaining three dates. This would indicate a problem with the scale on that particular date.

### **3.4 Kentucky's Current WIM Calibration Procedures**

Kentucky's current procedure for calibrating WIM capacitance pads follows, in general, the method proposed by Southgate and Deacon (11). The pad being calibrated is placed in the traffic stream of a permanent weigh station. The manufacturer's suggested calibration factor is set on the pad and approximately 100 trucks are weighed. The calibration factor is then reduced by 10, and an additional 100 trucks are weighed. The calibration factor is further reduced to 20 less than the manufacturer's suggested factor, and 100 more trucks are weighed. The calibration factor is then alternately set at 10 and

at 20 above the manufacturer's suggested factor and an additional 100 trucks are weighed at each calibration point. This is a total of 500 trucks that are weighed. The static weights from the weigh station for these 500 trucks are obtained and an average static-to-WIM ratio is computed for each calibration point. These five static-to-WIM ratios are plotted as a function of the calibration factor that was set on the pad. A line is drawn through this plot, and the calibration factor at which the line intersects a static-to-WIM ratio of 1.0 is chosen as the calibration factor for the pad.

## **4.0 SCALE CALIBRATION AND CORRELATION**

### **4.1 Field Testing**

On-site calibration and correlation of five different WIM systems were conducted in May and June of 1995. The site was located near Milepost 42 on the eastbound lanes of Interstate 64 in Shelby County. The reported weights of each system were compared to weights obtained from a slow-speed WIM system located at a permanent weigh station situated approximately four miles (Milepost 38) upstream from the site.

The five scales consisted of a Golden River capacitance pad, an IRD piezoelectric cable installed in a rigid slab, an IRD piezoelectric cable installed in a flexible pavement, a bridge WIM installed on a simple span, and a bridge WIM installed on a continuous span. The slow-speed WIM at the weigh station was a load cell pit scale.

The axle weights of selected Type 9 (a combination tractor with semi-trailer having a total of five axles) vehicles were recorded at the weigh station and radioed ahead to the WIM calibration site. The axle weights of these same vehicles were recorded by each of the various WIM scales to be compared later with the weights from the weigh station. Because of time constraints, only 94 Type 9 vehicles were weighed during the field test. (Some of the WIM systems being calibrated have less than 94 vehicles because some vehicles did not trigger all the systems.)

### **4.2 Analysis of Field Data**

Figures 3 through 7 are plots of the gross vehicle weights measured by the weigh station versus the gross vehicles weights as measured by the five WIM

systems at the calibration site. The number of data points varies from figure to figure because some of the calibration vehicles did not trigger all of the systems. For each of the systems, there is a general increasing trend with increasing weight. However, there is considerable scatter in all of the systems.

Figures 8 and 9 show the distribution of steering axle weights and vehicle gross weights, respectively, from the permanent weigh station. Figure 9 also shows the distribution of gross weights from the piezoelectric cable installed in the rigid slab. Clearly, the two distributions are markedly different. Although not shown, the distributions from the remaining four systems also varied widely from the weigh station distribution. Furthermore, there were not two distinct peaks in the gross weight distributions as might be expected from interstate traffic (for example, see Figure 2). The distributions tend to be more variable across the range of weights, with more but smaller peaks.

This variability in the distributions can probably be explained by the method used to sample the traffic stream. Firstly, only Type 9 vehicles were sampled. Secondly, only a selected number of Type 9's in the traffic stream were weighed. When the weigh station became very busy and vehicles waiting to be weighed began to fill the approach ramp, research personnel did not weigh any trucks. The reason for this was that the researchers had to stop each vehicle that was to be weighed on the scales at the calibration site and ask them to remain in the right lane until they had crossed the WIM calibration site. This tended to slow down the weighing process at the weigh station.

As mentioned earlier, recommendations range from 400 to 500 as the minimum number of samples required for statistically sampling the traffic stream. Because only 94 were sampled, it is expected that the shapes of the weight distributions were significantly influenced by the small sample size.

Although the sample size was smaller than recommended, Figure 10 indicates that the accumulative mean of the gross vehicle weight from the weigh station was rapidly converging. Also, Figure 11 indicates that the calibration factor (to be defined and discussed later) between the weigh station and the piezoelectric cable in the rigid slab appeared to be converging as the number of samples increased. Therefore, it was concluded that in this instance the number of samples was sufficient to permit calibration between the various WIM systems.

The distribution functions illustrated in Figure 9 are informative and some states (19) use such distribution functions in that particular form to assist them

in determining scale drift and calibration (by visually observing the change in shape). However, little or no quantitative information can be obtained from those functions in their current form. If the distribution functions in Figure 9 are plotted as cumulative distribution functions, as shown in Figure 12, regression analysis can be performed on the data and calibration factors can be developed between the scale systems.

It is not easy to find an appropriate regression model for the curves in Figure 12 because of their unusual shape. However, if the data in Figure 12 are converted to a transformed "*Weibull failure distribution*" (20, 21), a linear regression analysis can be performed on the data permitting development of calibration factors between the weigh station and the other WIM systems. The transformed Weibull distribution is of the following form:

$$\text{Log}(F) = C_0 + C_1 * \text{Log}(W) + C_2 * [\text{Log}(W)]^2 \quad (1)$$

where:

$C_0, C_1, C_2$  = Regression constants,  
 $F = 1 / (1-f)$ ,  
 $W$  = Weight in KIPS, and  
 $f$  = The cumulative percent at weight,  $W$ .

Figures 13 through 16 show the transformed distribution function and the results of the regression analysis on each distribution for the gross vehicle weights. Each figure shows the function for the weigh station as compared to one of the five systems at the calibration site. Figures 17 through 20 show the same information for the steering axles. A comparison between the weigh station and the bridge WIM located on the simple span for gross vehicle weights and a comparison between the weigh station and the capacitance pad for steering axles are not shown because the data were not available.

The calibration factor (or should probably more properly be called "calibration function") for a particular WIM system is defined as the ratio of the distribution function for the weigh station to the distribution function for the WIM system being calibrated. These calibration functions also are shown in Figures 13 through 20. It is clear from these figures that the calibration between two systems should be a continuous function and not a single calibration factor. This confirms research reported by Hamrick and Fugit (14) where they indicated that multi-calibration factors should be used, varying with the weight range. Figure 21 (taken directly from Reference 14) shows a portion



of their reported data illustrating the relationship between calibration factor and weight range.

Examination of Figures 13 through 20 indicates that the capacitance pad weighed consistently higher than the weigh station, while the two piezoelectric cables weighed less than the weigh station. There are two possible explanations. The first possibility is the calibration points on the individual scales at which the weights were taken may have inadvertently produced those results (the calibration points were not changed during the field testing). However, a second possibility is that the pad produced higher weights than the weigh station because it is slightly raised above the pavement surface, thereby receiving a small impact from each wheel load. The piezoelectric cables were installed in a narrow groove in the pavement. Since the groove is considerably narrower than a tire footprint, it is probable that some of the tire load was bridging over the cable. This would cause the load to be less on the cable. Both bridge WIM systems consistently weighed less than the weigh station.

Lack of proper calibration can dramatically affect the results of ESAL calculations based on the data from the WIM scale. The following is an example of an ESAL calculation based on data obtained from the calibration site. Also, for purposes of illustration, only the data from the piezoelectric cable in the rigid slab are used. The following are the assumptions were made and the values that were used in the analysis.

- *One-way AADT = 28,200,*
- *Trucks = 23% of traffic stream,*
- *All trucks = Type 9,*
- *Approximately 6,500 Type 9's per day, and*
- *Although not correct, for the sake of simplicity, it was assumed the distribution of Type 9's was the same for each day of the year.*

Using Kentucky's damage factors and the weights reported from the weigh station, the 94 Type 9's in the weigh station sample were the equivalent of 72 ESAL's ( $e_{ws}$ ). The 83 Type 9's in the PCC piezoelectric cable sample produced the equivalent of 40 ESAL's ( $e_{upcc}$ ) when using the reported weights from the uncalibrated scale. The number of ESAL's per day from each of the two scales, was determined from the following equations:

$$e_{dws} = e_{ws} * 6,500 / 94, \text{ or} \tag{2}$$

$$e_{dupcc} = e_{upcc} * 6,500 / 83 \tag{3}$$

where:

$e_{ws}$  = number of ESAL's from weigh station sample (72),  
 $e_{upcc}$  = number of ESAL's from PCC piezoelectric cable sample (40),  
 $e_{dws}$  = number of ESAL's per day from weigh station, and  
 $e_{dupcc}$  = number of ESAL's per day from PCC piezoelectric cable.

Solving Equations 2 and 3 yields:

$$e_{dws} = 4,979 \text{ ESAL's/day} \quad (4)$$

$$e_{dupcc} = 3,133 \text{ ESAL's/day} \quad (5)$$

The predicted annual ESAL's for each scale equals:

$$e_{aws} = e_{dws} * 365 = 1,817,335 \text{ ESAL's/year, and} \quad (6)$$

$$e_{aupcc} = e_{dupcc} * 365 = 1,143,545 \text{ ESAL's/year.} \quad (7)$$

The percent error produced by using the reported weights from the uncalibrated PCC piezoelectric cable would be

$$\text{Percent Error} = [(e_{aws} - e_{aupcc}) / e_{aws}] * 100 = 37\%. \quad (8)$$

Using the continuous calibration curve developed from the distribution function for the PCC piezoelectric cable (see Figure 14), the number of ESAL's produced by the 83 Type 9's ( $e_{cpcc}$ ) would be equal to 61. Using the same calculation procedure as for the uncalibrated scale above, the percent error for the calibrated scale is obtained.

$$e_{dcpcc} = e_{cpcc} * 6,500 / 83 = 4,777 \text{ ESAL's/day, and} \quad (9)$$

$$e_{acpcc} = e_{dcpcc} * 365 = 1,743,605 \text{ ESAL's/year.} \quad (10)$$

Again, the percent error for the continuously calibrated scale is calculated from the following:

$$\text{Percent Error} = [(e_{aws} - e_{acpcc}) / e_{aws}] * 100 = 4\%. \quad (11)$$

Clearly, a continuous calibration function greatly reduces the amount of error between the standard scale and the scale being calibrated.

A single-point calibration also can be calculated from the field data at the test site. This is the method used by most states to calibrate their systems. If the median calibration

factor from the calibration curve shown in Figure 14 (1.375) is chosen for scale calibration, the 83 Type 9's in the calibration sample would produce 47 ESAL's. Repeating the above calculations using this value for ESAL's, yields 1,339,878 ESAL's per year. This is an error of approximately 26 percent. This illustrates the disadvantage of a single-point calibration procedure.

Figure 22 is a plot of the corrected data of gross weights from the PCC piezoelectric cable where individual weights have been corrected using the continuous calibration function. A comparison with this figure with Figure 4 shows dramatic improvement when compared to the weights reported from the weigh station.

Table 1 lists the percent difference between the means of the gross weights of the uncalibrated and calibrated data and the mean of the gross weights of the weigh station for the five WIM systems. Percent difference between the means of the calibrated data and the mean of the weigh station data is dramatically reduced when compared with the uncalibrated data.

## 5.0 COMPUTER PROGRAM DEVELOPMENT

Information and procedures developed at the calibration site were used to develop a computer program to calculate distribution functions for WIM data sets and to calculate calibrations and correlations between WIM scales. The program is entitled "*WIMBOTH*". Appendix A is the User's Manual for the program. The procedures for running the program, and a description of the output files are discussed in detail in that manual.

The computer program also checks for drift in the scale each time a particular scale is used to collect a data set. The program first calculates a distribution function for the current data set. The distribution function is then integrated over the range of 0 to 1 to determine the area under the curve. If

$$f(W) = \text{Log}(F) = C_0 + C_1 * \text{Log}(W) + C_2 * [\text{Log}(W)]^2, \quad (12)$$

then

$$\int_0^1 f(W) = \text{Area under the curve.} \quad (13)$$

The magnitude of this area is then compared to the magnitude of the areas under the curves of the distribution functions of previous data sets collected by the same scale. If the change in area under the curve is a continuously increasing or decreasing function, it is likely the scale is drifting. However, if the area randomly increases and decreases from data set to data set, it is probable that the changes are due to small differences in the weight

distribution of the traffic stream and are not related to the scale. This method of checking for drift is illustrated in Figure 23. These areas are printed into one of the output files as explained in the User's Manual.

The program also checks for random errors. As random errors increase, the standard deviation of the distribution function will also increase. Figure 24 shows the relationship between increasing random errors and the distribution function. From statistics, the area bounded by plus and minus one standard deviation from the mean will include 66 percent of the data or sample population. In the cumulative distribution, this is equal to the difference between the 17th and 83rd percentiles. The program calculates this difference for each data set and prints it to an output file for the operator to check.

The program reads "Card 7" data files. The distribution function for that data is determined. A calibration function is calculated between the data set and a standard distribution function. The program then corrects each weight in the data set according to the calibration function and prints a "corrected" data file in "Card 7" format.

Figure 25 is a generalized flow chart of the program.

## **6.0 PROPOSED CALIBRATION PROCEDURE**

Based upon the calibration efforts of this study, the recommendations of Southgate and Deacon (11), and the experience of other state agencies, the following steps are recommended for calibration and correlations of WIM systems. This recommended procedure will allow all WIM systems in current use in the state to be standardized to one scale and will permit the operator to continuously check the state of calibration of each individual scale.

- A single permanent scale should be chosen as the standard scale that is to be used for calibrating all WIM systems in the state. This scale should be calibrated annually, and the calibration of its sensing unit should be traceable back to the National Bureau of Standards.
- All portable capacitance pads should be calibrated at least once annually. These pads should be calibrated in the same traffic stream as the previously chosen standard scale.
- Scientifically, it is best to calibrate the pads, as much as possible, by adjusting the electronics of the hardware. Therefore, the current procedure (discussed in Section 3.4) as recommended by Southgate and Deacon (14) should continue to be the first step in the calibration and correlation procedure for the pads. This step of the

procedure helps to insure the internal electronics are reasonably in balance. At this point in the calibration procedure, the pads have now been calibrated to a single-point calibration factor.

- To have a continuous function calibration factor, a second stage is necessary. After completing the previous step in the calibration procedure, it is necessary to obtain an additional 500 truck weights from the standard weigh station and the pads being calibrated. If the weigh station is weighing all of the trucks in the traffic stream, it is not necessary that each truck at the weigh station be correlated exactly with each truck that passes the WIM pads. It is simply necessary to have approximately 500 trucks in each sample taken in the same time frame.
- Use the computer program *WIMBOTH* to develop the transformed distribution function for the weigh station. Then use the same program to develop the continuous calibration factor for each WIM pad being calibrated. These calibration functions are then stored in one of the output files of the program to be recalled later.
- When any of the WIM pads are used in the future at some other location in the state, the data collected at that site are “run through” *WIMBOTH* and the data are corrected according to the appropriate calibration function. The calibration function that was developed for the gross vehicle weight is the one that is used to correct the weights. A new corrected data file is created with the reported weights calibrated against the standard scale.
- It is recommended that one WIM pad be reserved for the exclusive use of calibrating other permanent WIM stations located throughout the state. This pad probably should be calibrated more frequently than once annually.
- Whenever a permanent WIM site is to be calibrated, a minimum of 30 passes of a truck of known weight should be recorded by the scale. The calibration factor should be adjusted to produce a WIM-to-static weight ratio as close as possible to 1.0. The calibration pad should then be placed in the traffic stream and a minimum of 500 truck weights should be recorded. Both data sets are to be run through *WIMBOTH* to calculate the transformed distribution functions, and a calibration function developed between the two scales. The individual weights in the data set from the new permanent scale are then corrected according to the calibration function. However, this data must be corrected one additional time to calibrate it according to the standard scale. This is done by “correcting” the corrected data set using the calibration function of the calibration WIM pad.
- By following the previous steps, every WIM site in the state, whether permanent or portable, and the data collected at that site, can be correlated and calibrated to one

standard scale.

## **7.0 CONCLUSIONS AND RECOMMENDATIONS**

The concept of a continuous calibration function and its use in calibrating and correlating between WIM systems appears to provide great advantage over a single-point calibration in reducing errors between WIM-to-static weights.

It appears the continuous calibration function concept is applicable to all types of WIM systems.

It is recommended that the methodology of WIM calibration proposed in this study be adopted for field trials and procedural testing.

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**Table 1. Comparison of Mean Gross Weights and Standard Deviations for All WIM Systems at the Calibration Site with the Weigh Station.**

	WEIGH STATION	CAPACITANCE PAD		PIEZOELECTRIC CABLE				BRIDGE WIM			
				PCC		AC		SIMPLE SPAN		CONT. SPAN	
		UC	C	UC	C	UC	C	UC	C	UC	C
MEAN	53.2	65.8	54.0	36.6	54.0	35.3	53.7	22.2	NA	46.9	57.0
STANDARD DEVIATION	16.2	27.7	17.5	15.4	15.2	18.3	14.5	26.6	NA	33.0	15.3
PERCENT DIFFERENCE	-----	24.0	1.5	31.2	1.5	33.6	0.9	58.3	NA	11.8	7.1
NO. OF OBSERVATIONS	94	86		83		77		15		76	

Percent Difference = (Mean - Weigh Station Mean) / (Weigh Station Mean) \* 100.

UC = Uncalibrated Scale.

C = Calibrated Scale.

# TYPES OF ERRORS

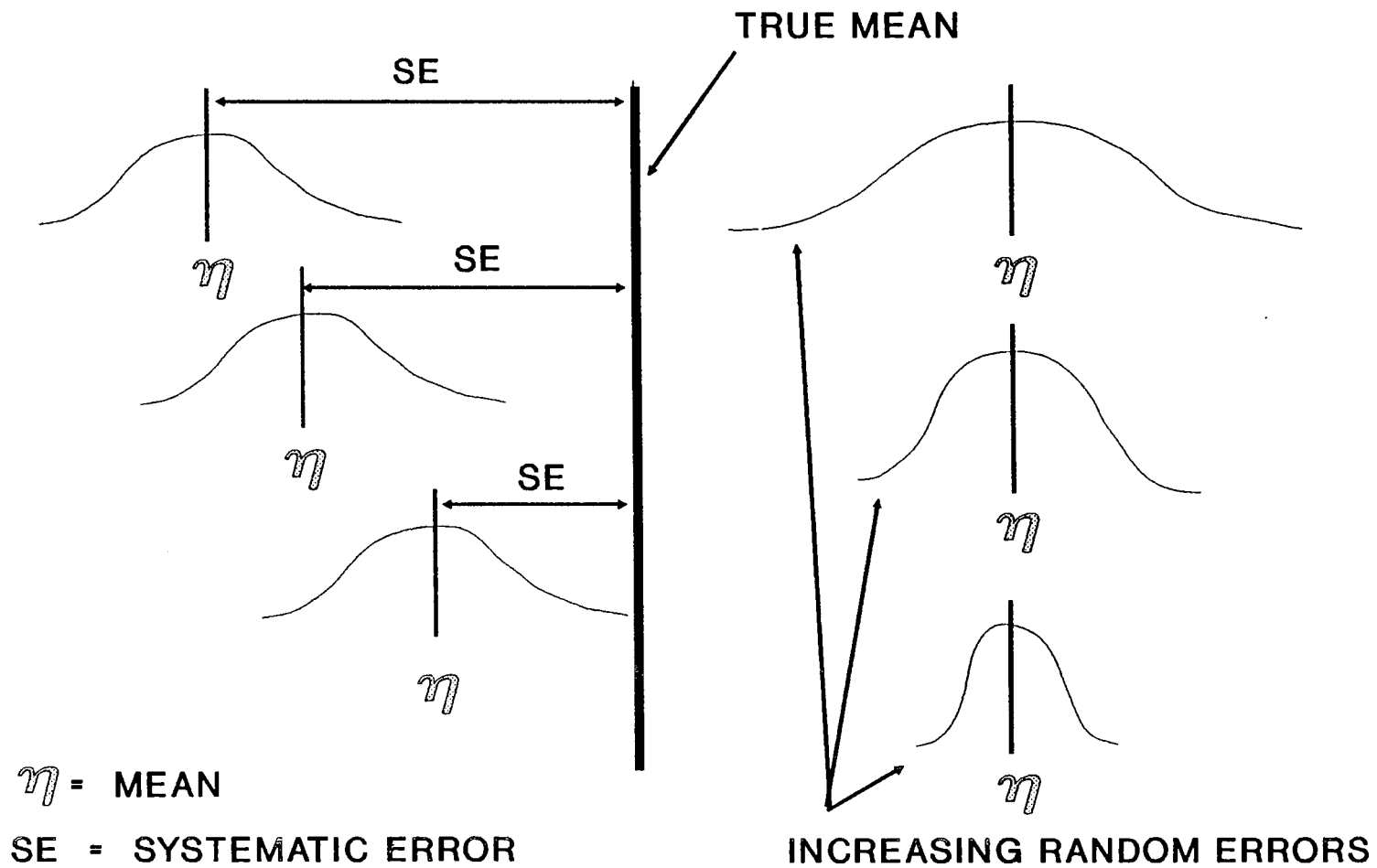
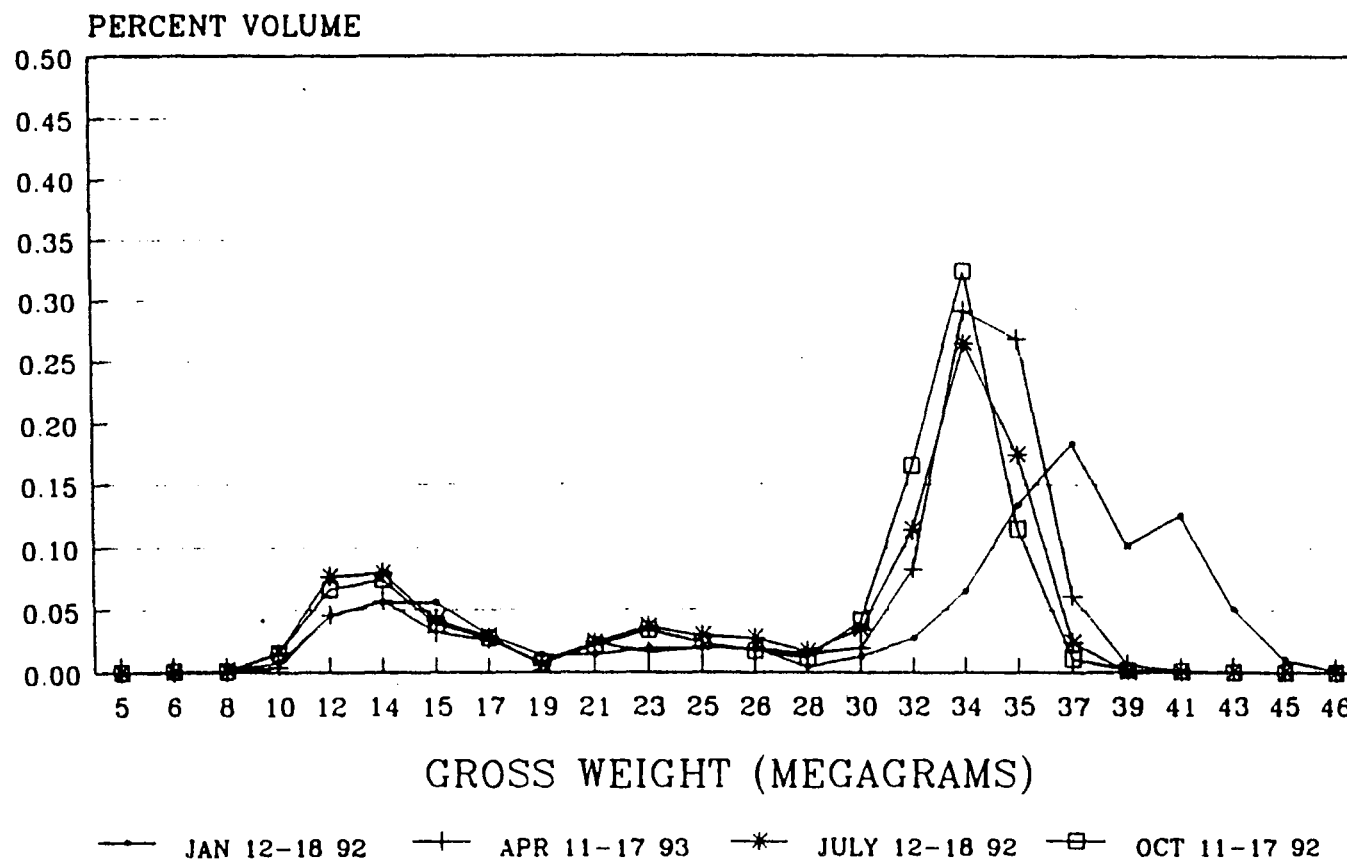


Figure 1. Types of Possible Errors.



EASTBOUND, RIGHT LANE

**Figure 2. Typical Gross Weight Distributions (from Reference 19).**

# WEIGH STATION vs. CAPACITANCE PAD

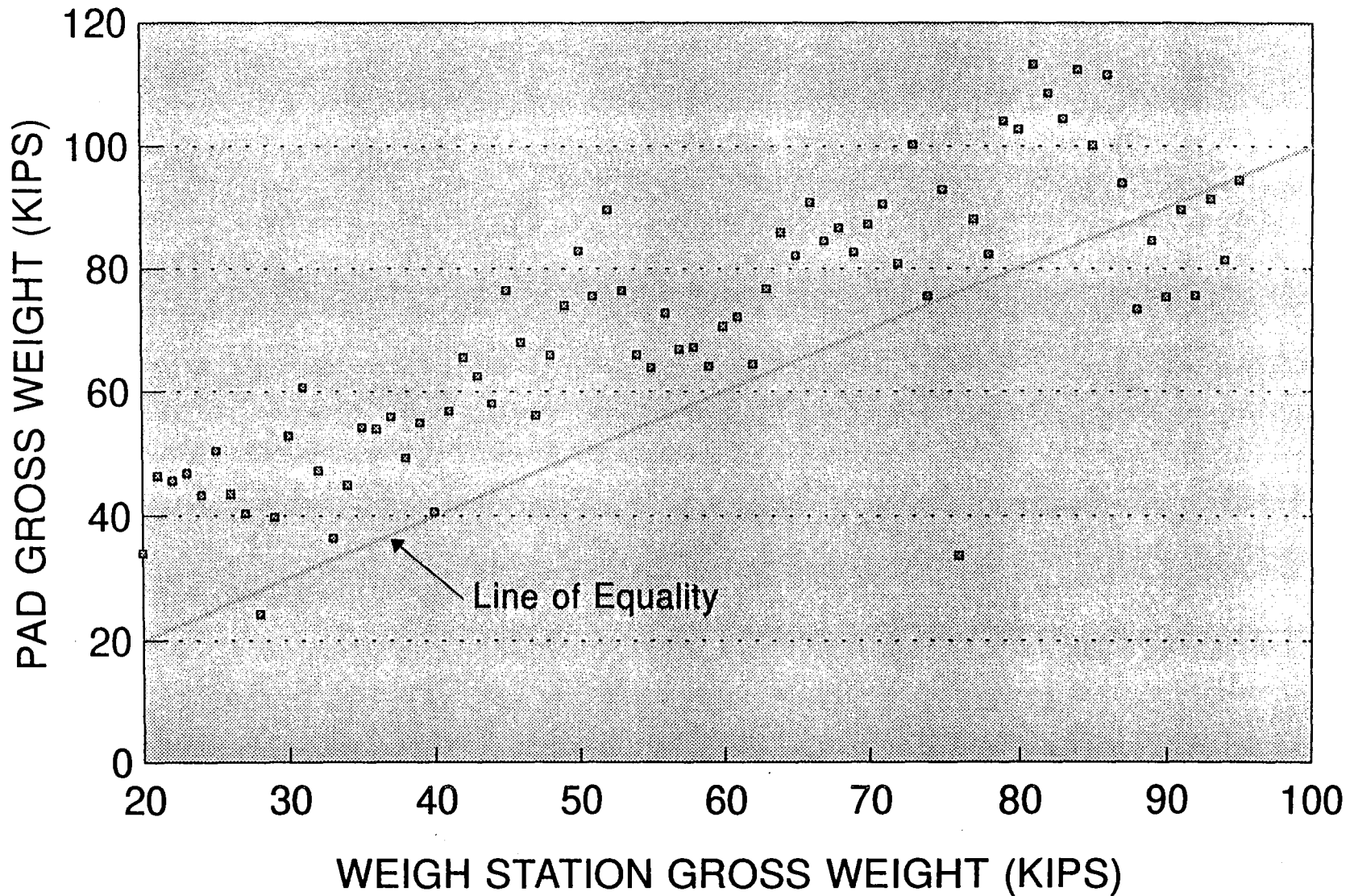


Figure 3. Gross Weights of Capacitance Pad vs. Weigh Station.

# WEIGH STATION vs. PCC PIEZOELECTRIC CABLE

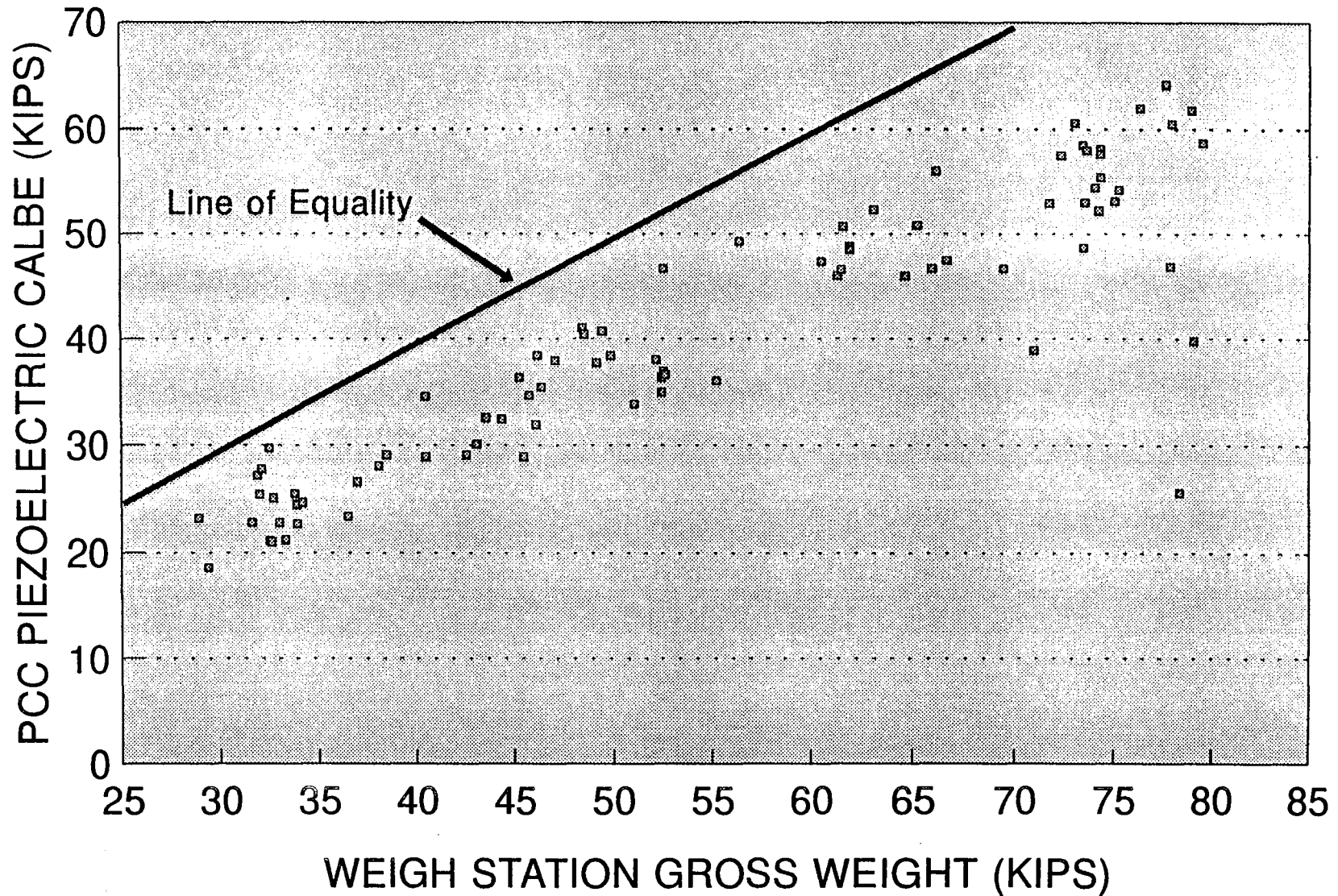


Figure 4. Gross Weights of PCC Piezoelectric Cable vs. Weigh Station.

# WEIGH STATION vs. AC PIEZOELECTRIC CABLE

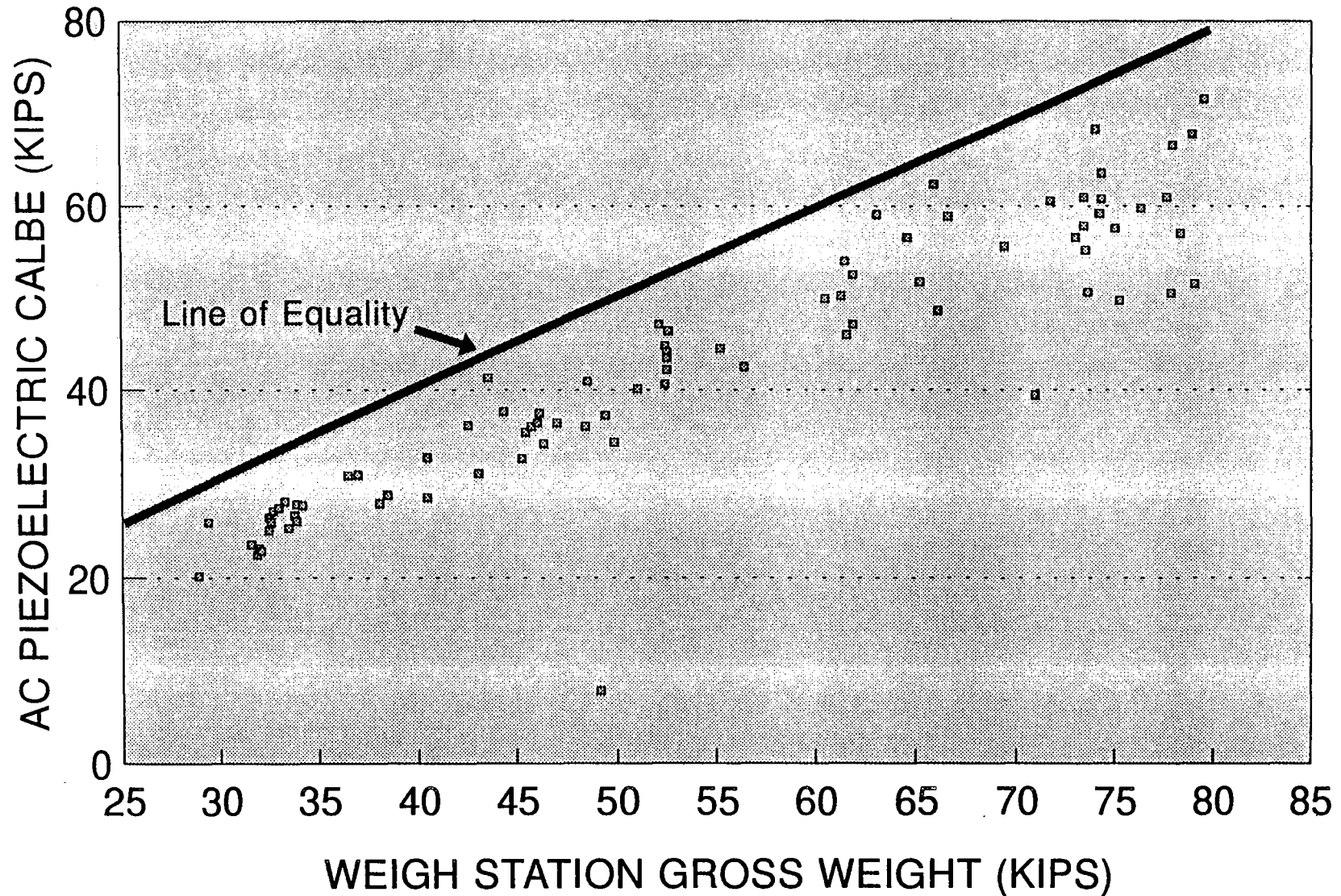
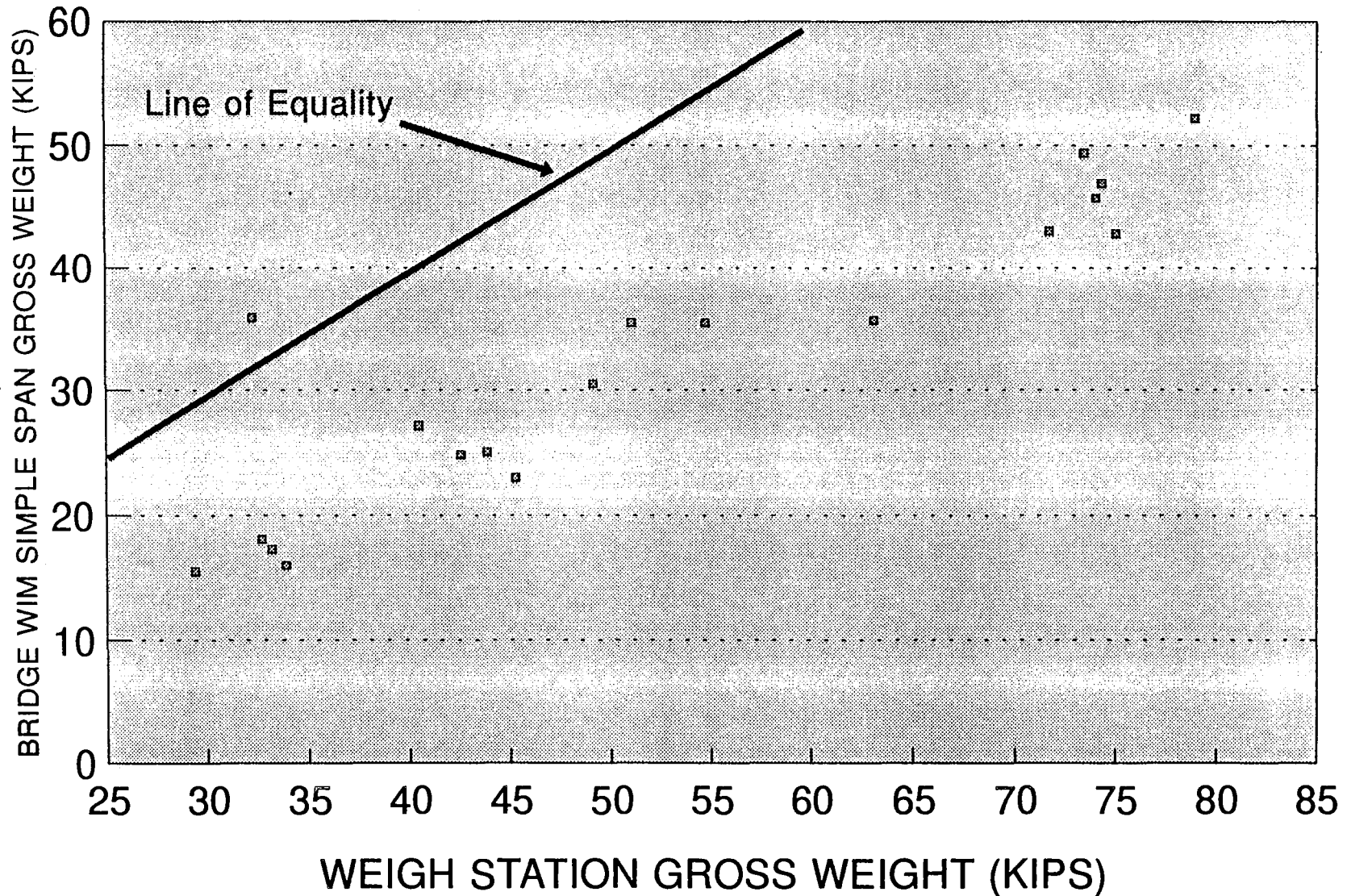


Figure 5. Gross Weights of AC Piezoelectric Cable vs. Weigh Station.

# WEIGH STATION vs. BRIDGE WIM (SIMPLE SPAN)



**Figure 6. Gross Weights of Bridge WIM (Simple Span) vs. Weigh Station.**



# WEIGH STATION vs. BRIDGE WIM (CONTINUOUS)

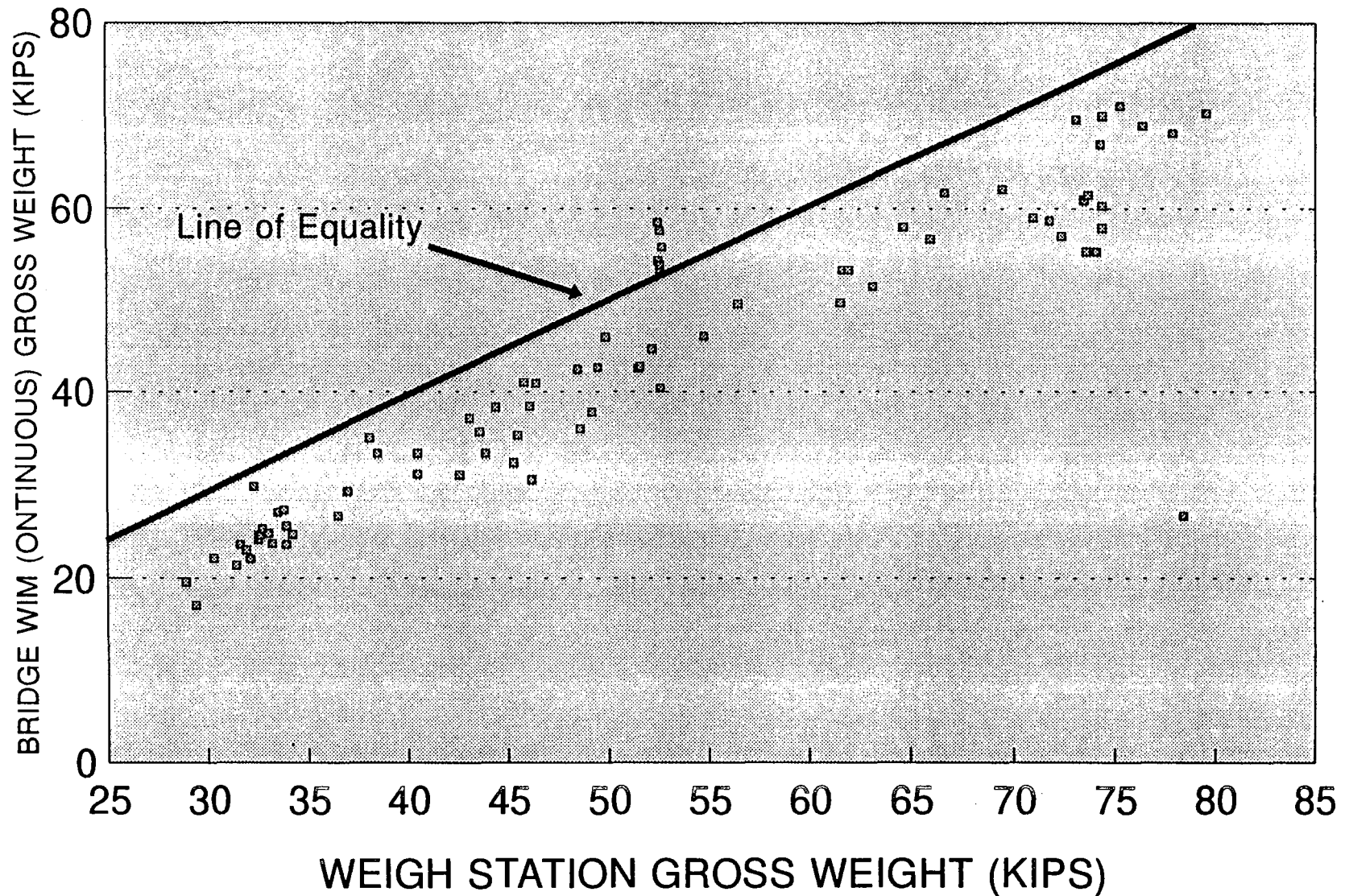
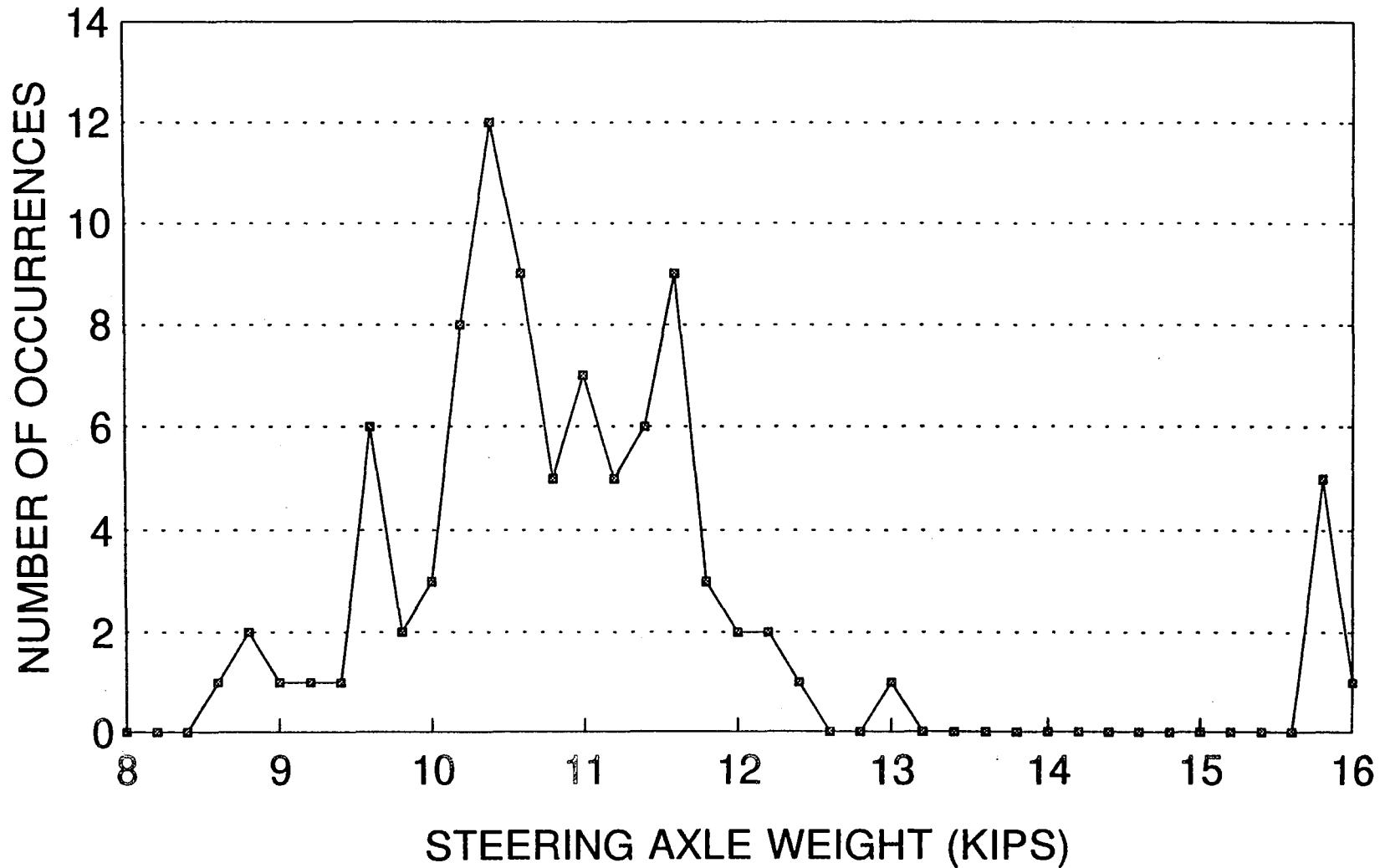


Figure 7. Gross Weights of Bridge WIM (Continuous) vs. Weigh Station.

# DISTRIBUTION OF STEERING AXLE WEIGHTS WEIGH STATION

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**Figure 8. Distribution of Steering Axle Weights for Weigh Station.**

# DISTRIBUTION OF GROSS WEIGHTS

WEIGH STATION vs. PIEZOELECTRIC CABLE (PCC)

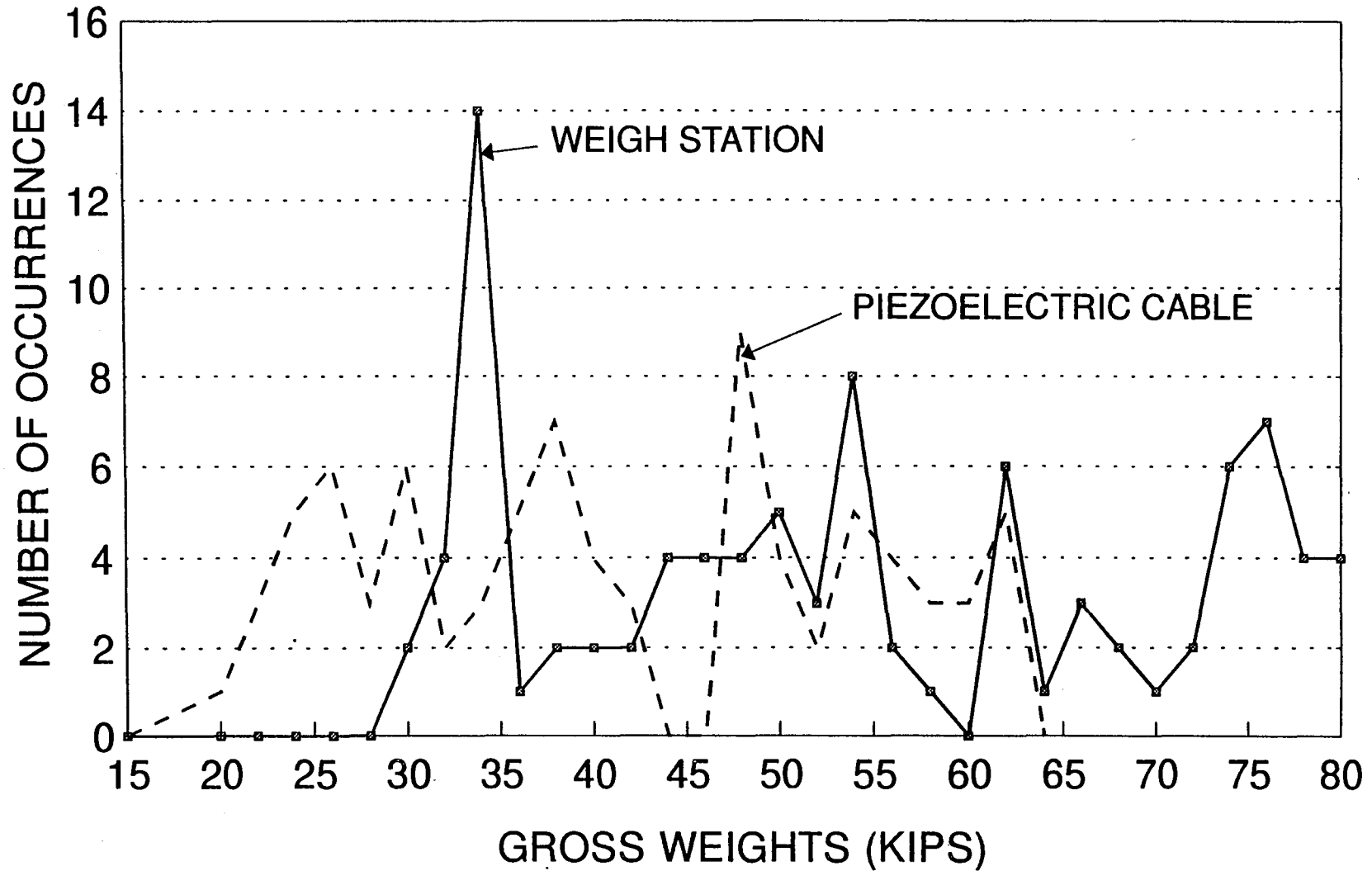
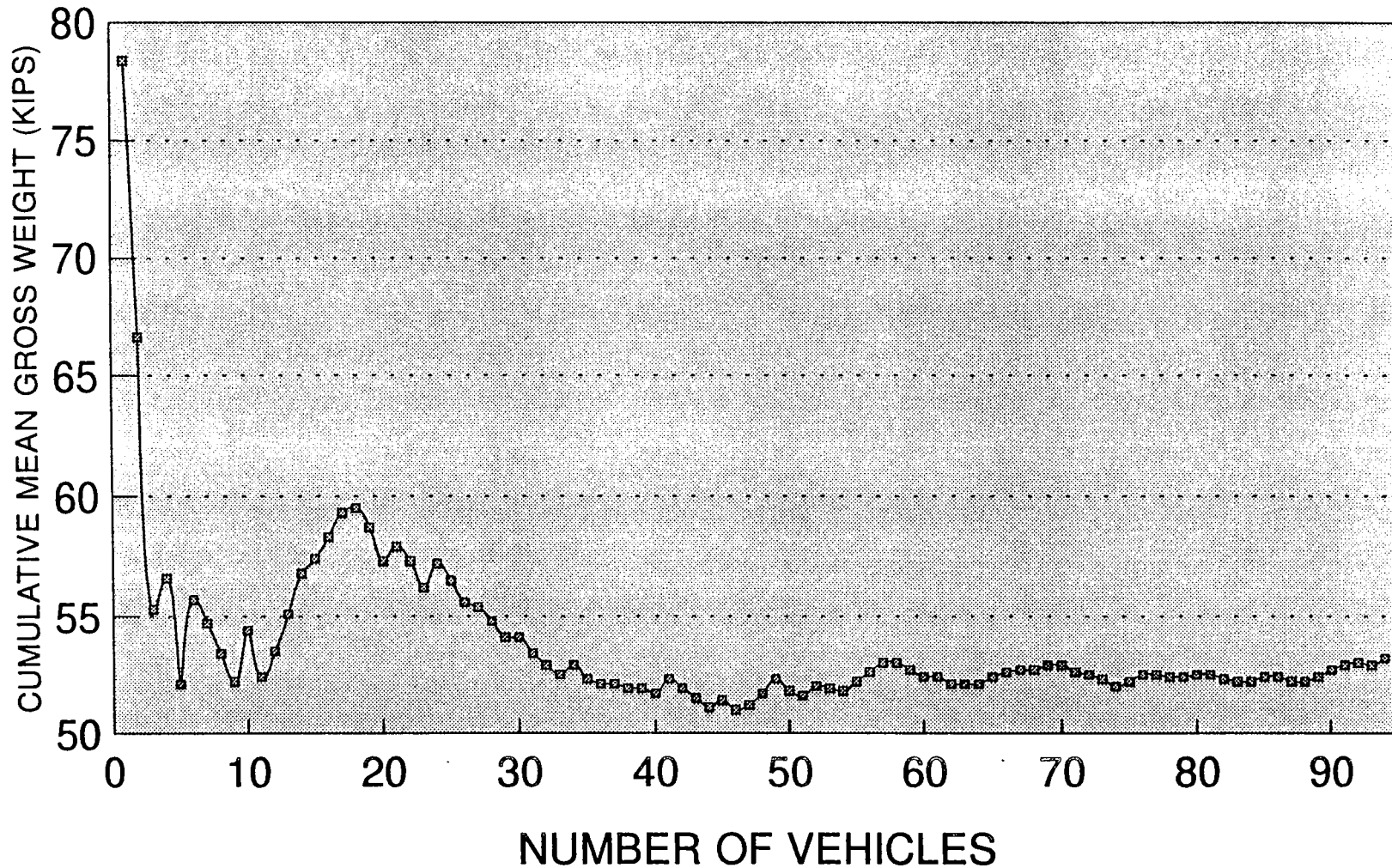
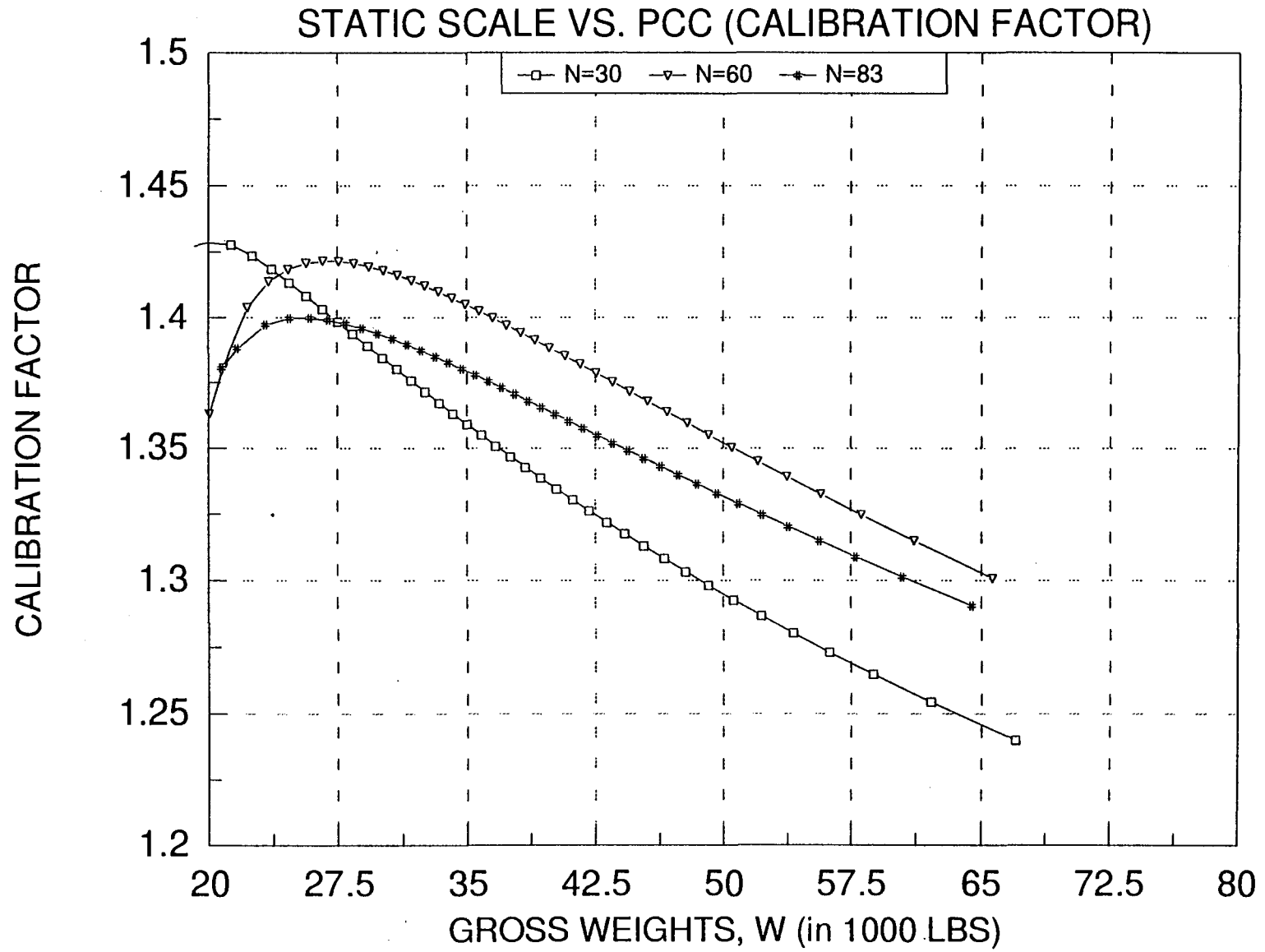


Figure 9. Distribution of Gross Weights of Weigh Station and PCC Cable.

# CUMULATIVE MEAN GROSS WEIGHT (KIPS) AS A FUNCTION OF NUMBER OF VEHICLES FOR THE WEIGH STATION

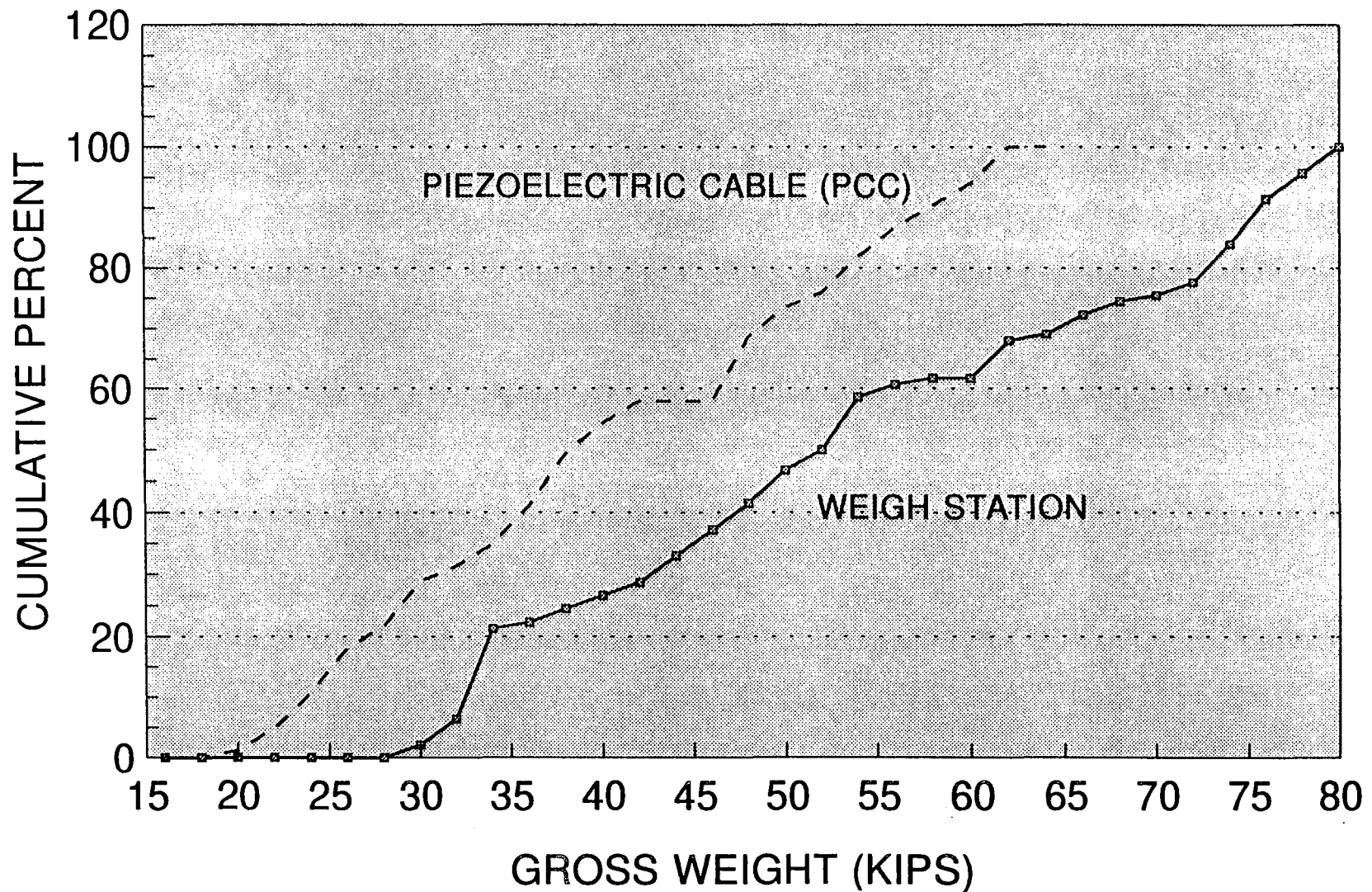


**Figure 10. Cumulative Mean Gross Weight as a Function of Number of Vehicles.**



**Figure 11. Effect of Number of Vehicles on Calibration Factor.**

# CUMULATIVE DISTRIBUTION OF GROSS WEIGHTS WEIGH STATION vs. PIEZOELECTRIC CABLE (PCC)



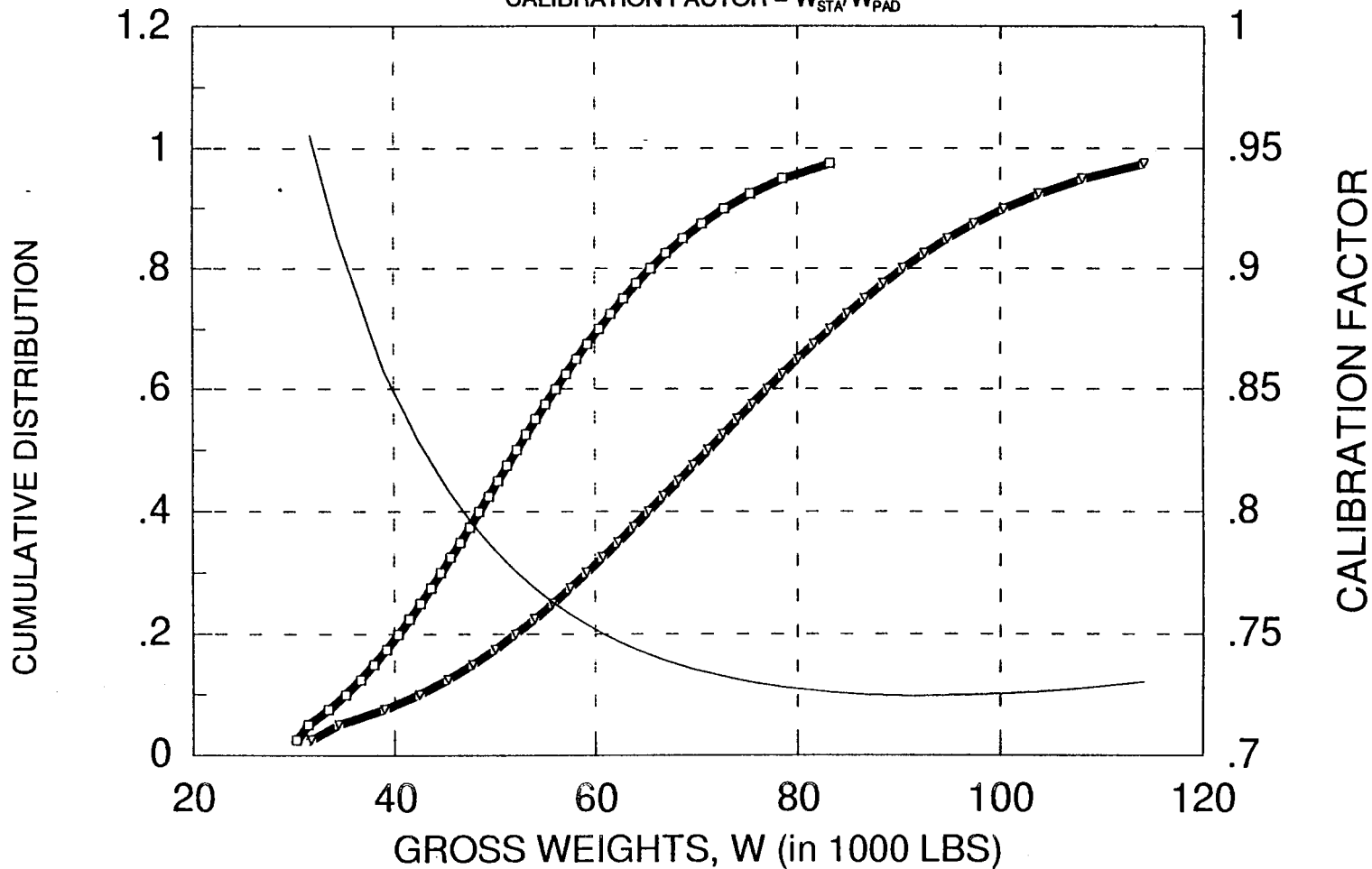
**Figure 12. Cumulative Distribution of Gross Weights for Weigh Station and PCC Piezoelectric Cable.**

### GROSS WEIGHT DISTRIBUTION (WEIGH STATION VS. PAD)

-▽ - PAD:  $\text{LOG}(F) = 2.008 + 0.302 \cdot W + 0.022 \cdot W^2$  ( $R^2 = 0.96$ )

-□ - STATION:  $\text{LOG}(F) = 1.869 + 0.312 \cdot W + 0.058 \cdot W^2$  ( $R^2 = 0.93$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}}/W_{\text{PAD}}$



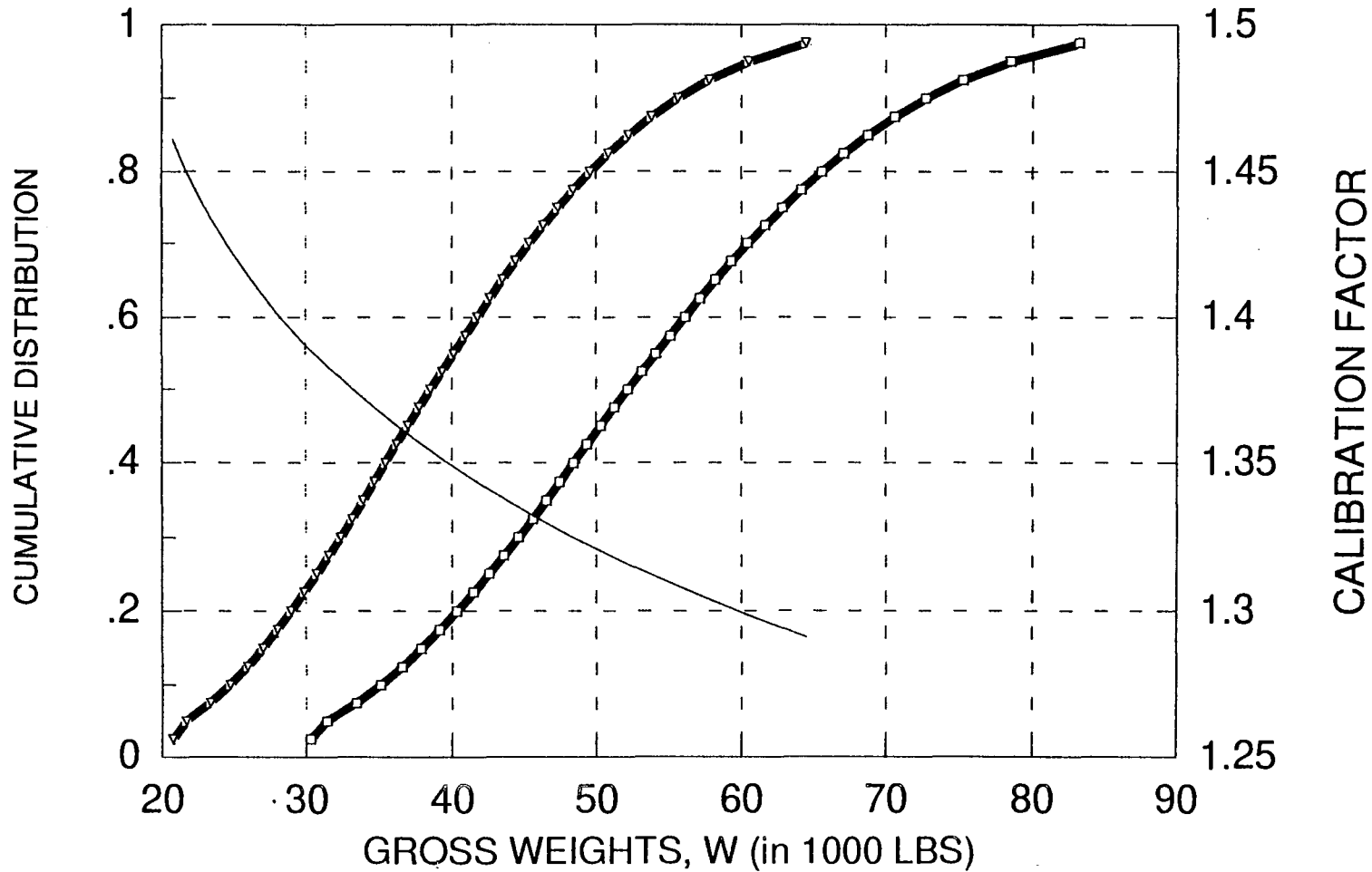
**Figure 13. Gross Weight Distribution Functions for Weigh Station and Capacitance Pad.**

### GROSS WEIGHT DISTRIBUTION (WEIGH STATION VS. PCC CABLE)

-□ - STATION:  $\text{LOG}(F) = 1.869 + 0.312 \cdot W + 0.058 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - PCC:  $\text{LOG}(F) = 1.753 + 0.343 \cdot W + 0.061 \cdot W^2$  ( $R^2 = 0.97$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}} / W_{\text{PCC}}$



**Figure 14. Gross Weight Distribution Functions for Weigh Station and PCC Piezoelectric Cable.**

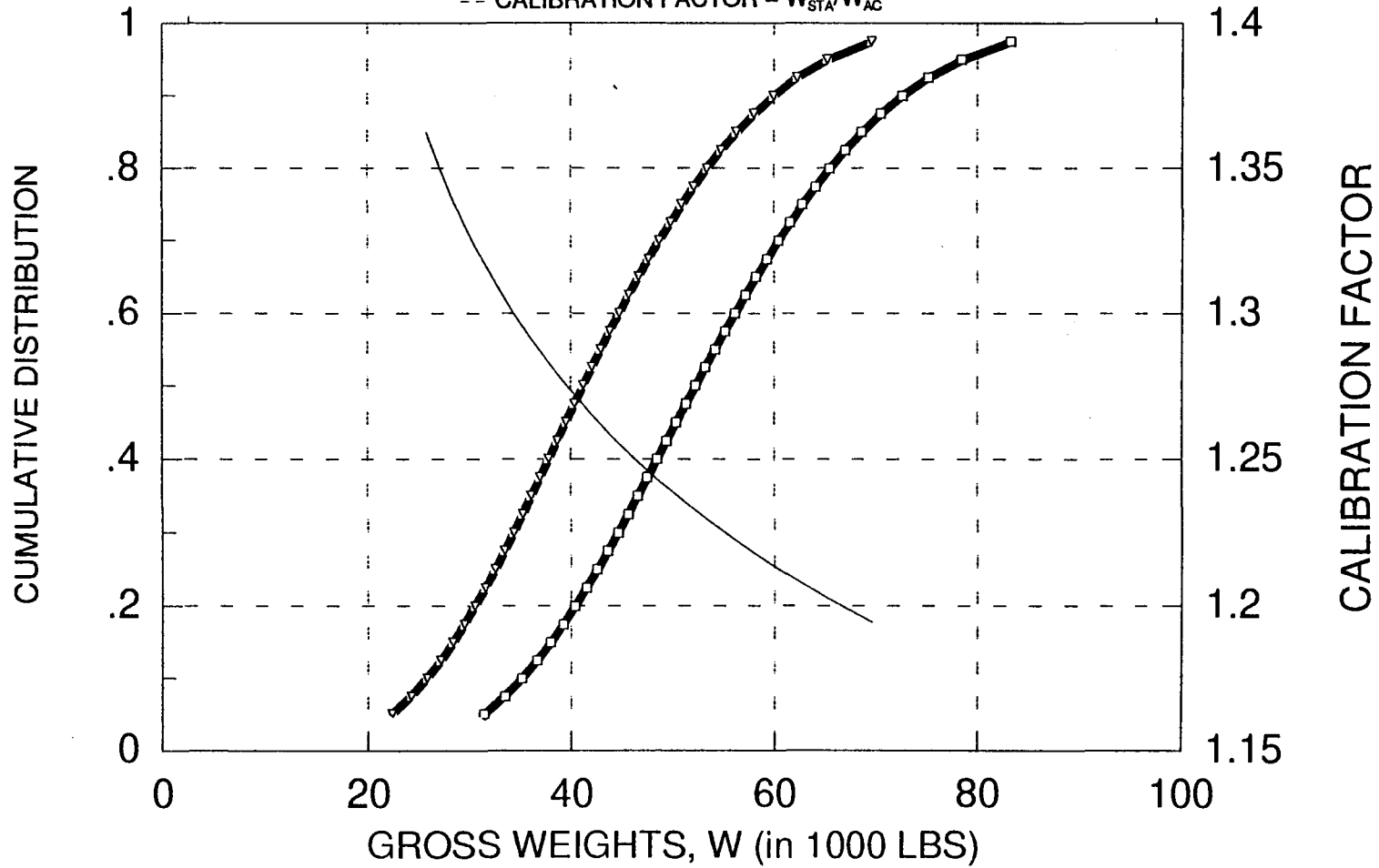


**GROSS WEIGHT DISTRIBUTION (WEIGH STATION VS. AC CABLE)**

-□ - STATION:  $\text{LOG}(F) = 1.869 + 0.312 \cdot W + 0.058 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - AC:  $\text{LOG}(F) = 1.785 + 0.350 \cdot W + 0.059 \cdot W^2$  ( $R^2 = 0.99$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}}/W_{\text{AC}}$



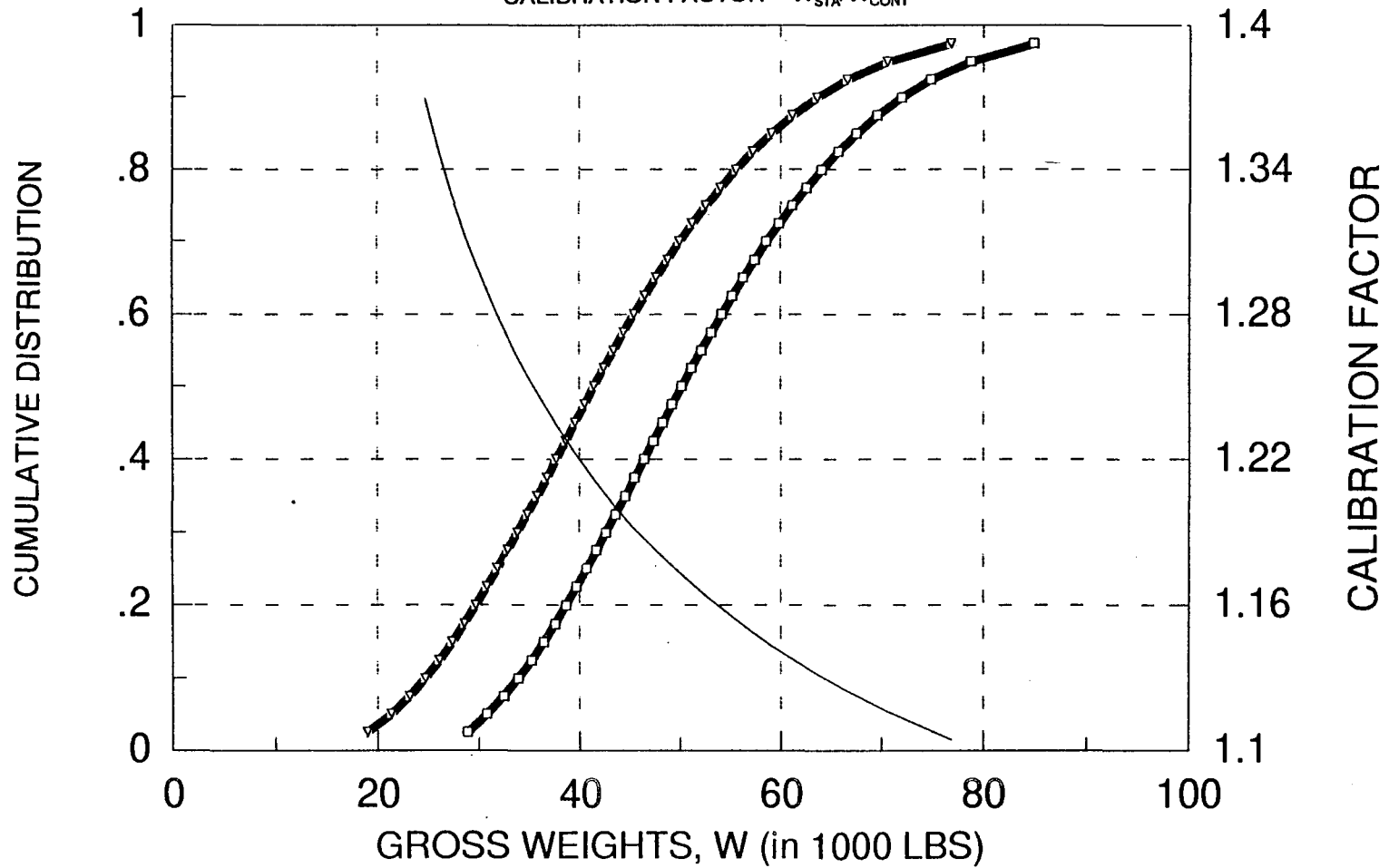
**Figure 15. Gross Weight Distribution Functions for Weigh Station and AC Piezoelectric Cable.**

**GROSS WEIGHT DISTRIBUTION (WEIGH STATION VS. BRIDGE CONT.)**

-□ - STATION:  $\text{LOG}(F) = 1.869 + 0.312 \cdot W + 0.058 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - CONT:  $\text{LOG}(F) = 1.803 + 0.389 \cdot W + 0.062 \cdot W^2$  ( $R^2 = 0.97$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}}/W_{\text{CONT}}$



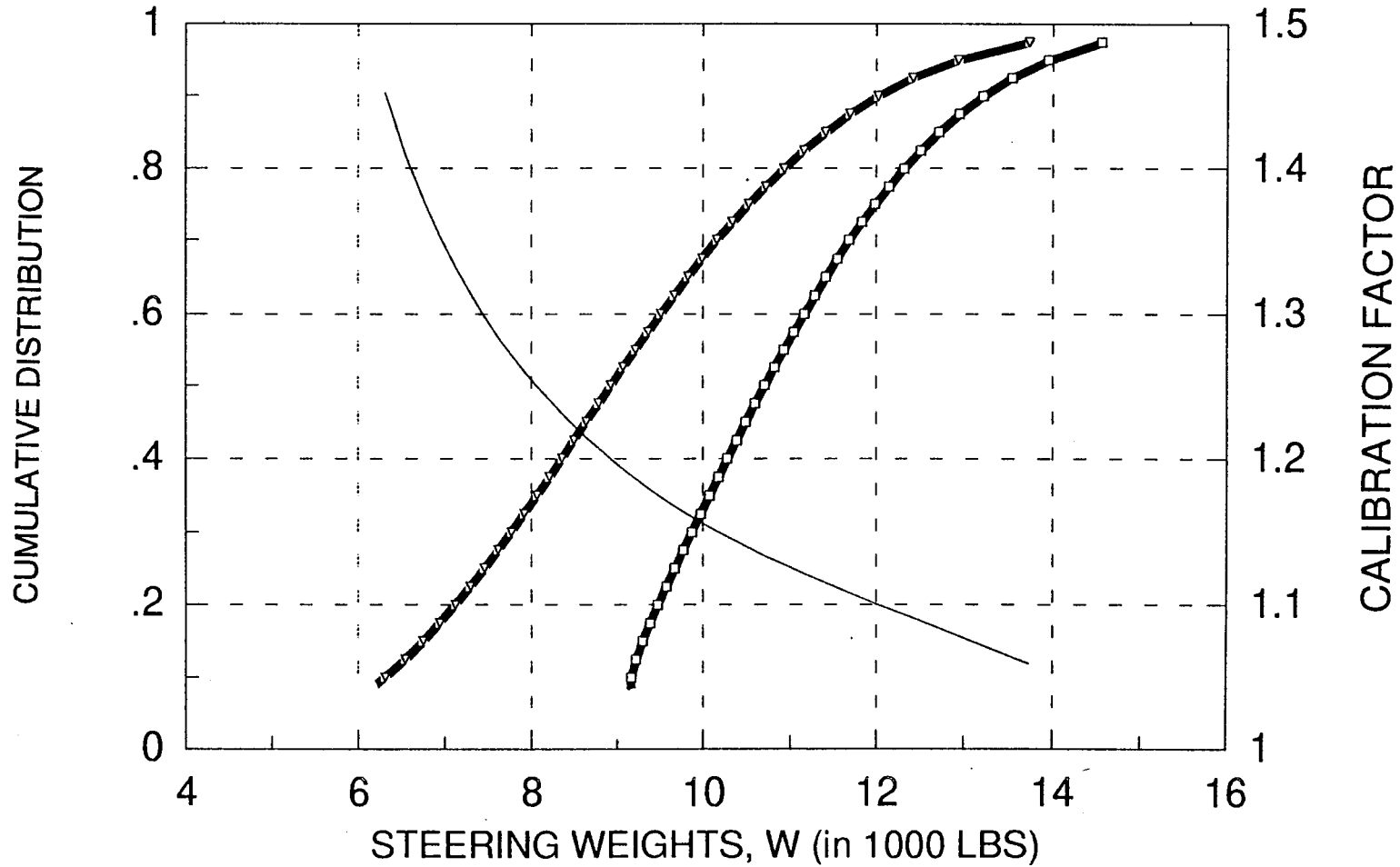
**Figure 16. Gross Weight Distribution Functions for Weigh Station and Bridge WIM (Continuous).**

### STEERING AXLE DISTRIBUTION (WEIGH STATION VS. AC CABLE)

□ - STATION:  $\text{LOG}(F) = 1.134 + 0.245 \cdot W + 0.087 \cdot W^2$  ( $R^2 = 0.93$ )

▽ - AC:  $\text{LOG}(F) = 1.080 + 0.273 \cdot W + 0.048 \cdot W^2$  ( $R^2 = 0.92$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}} / W_{\text{AC}}$



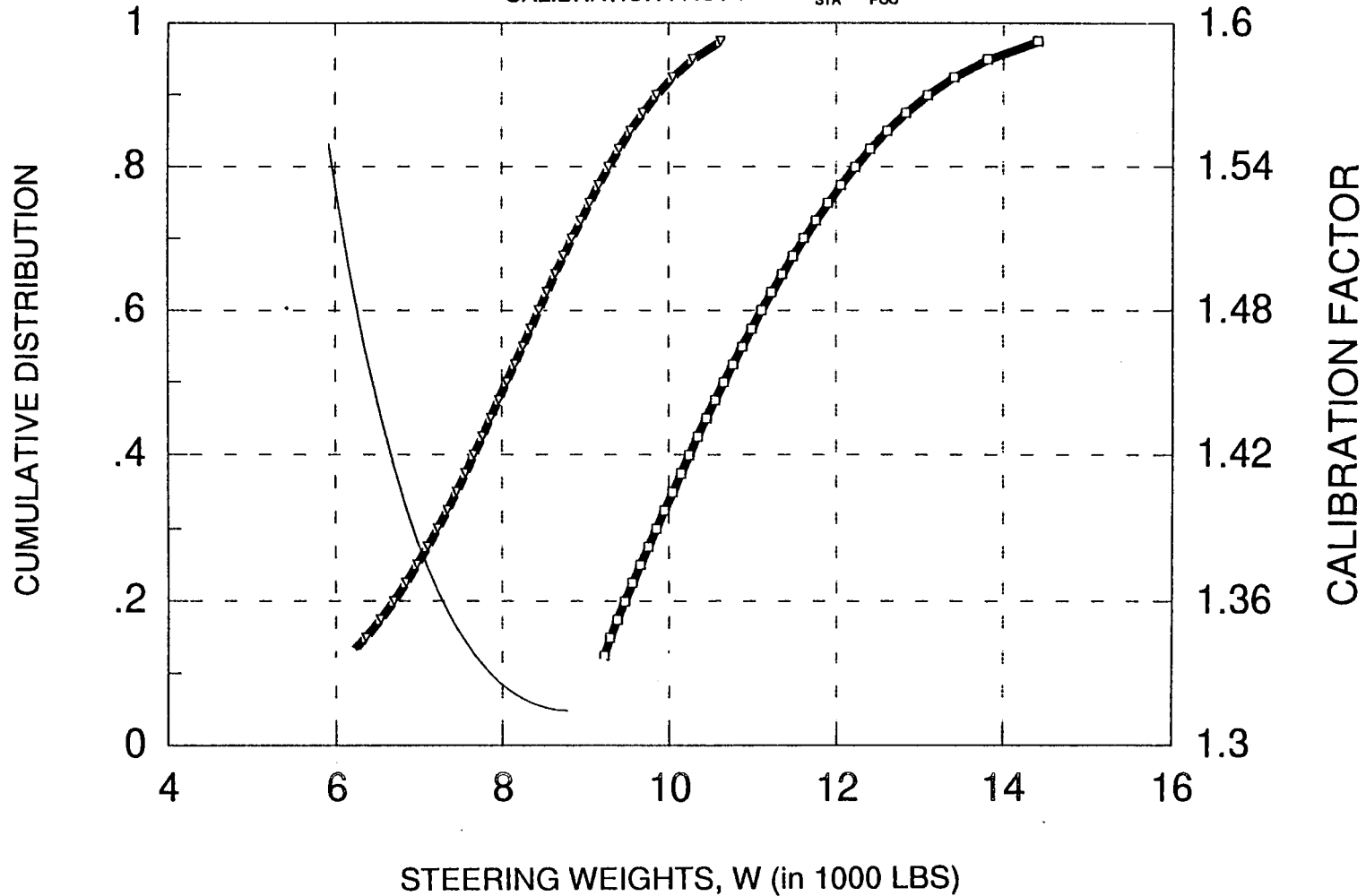
**Figure 17. Steering Axle Weight Distribution for Weigh Station and AC Piezoelectric Cable.**

### STEERING AXLE DISTRIBUTION (WEIGH STATION VS. PCC CABLE)

-□ - STATION:  $\text{LOG}(F) = 1.134 + 0.245 \cdot W + 0.087 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - PCC:  $\text{LOG}(F) = 0.997 + 0.176 \cdot W + 0.011 \cdot W^2$  ( $R^2 = 0.97$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}} / W_{\text{PCC}}$



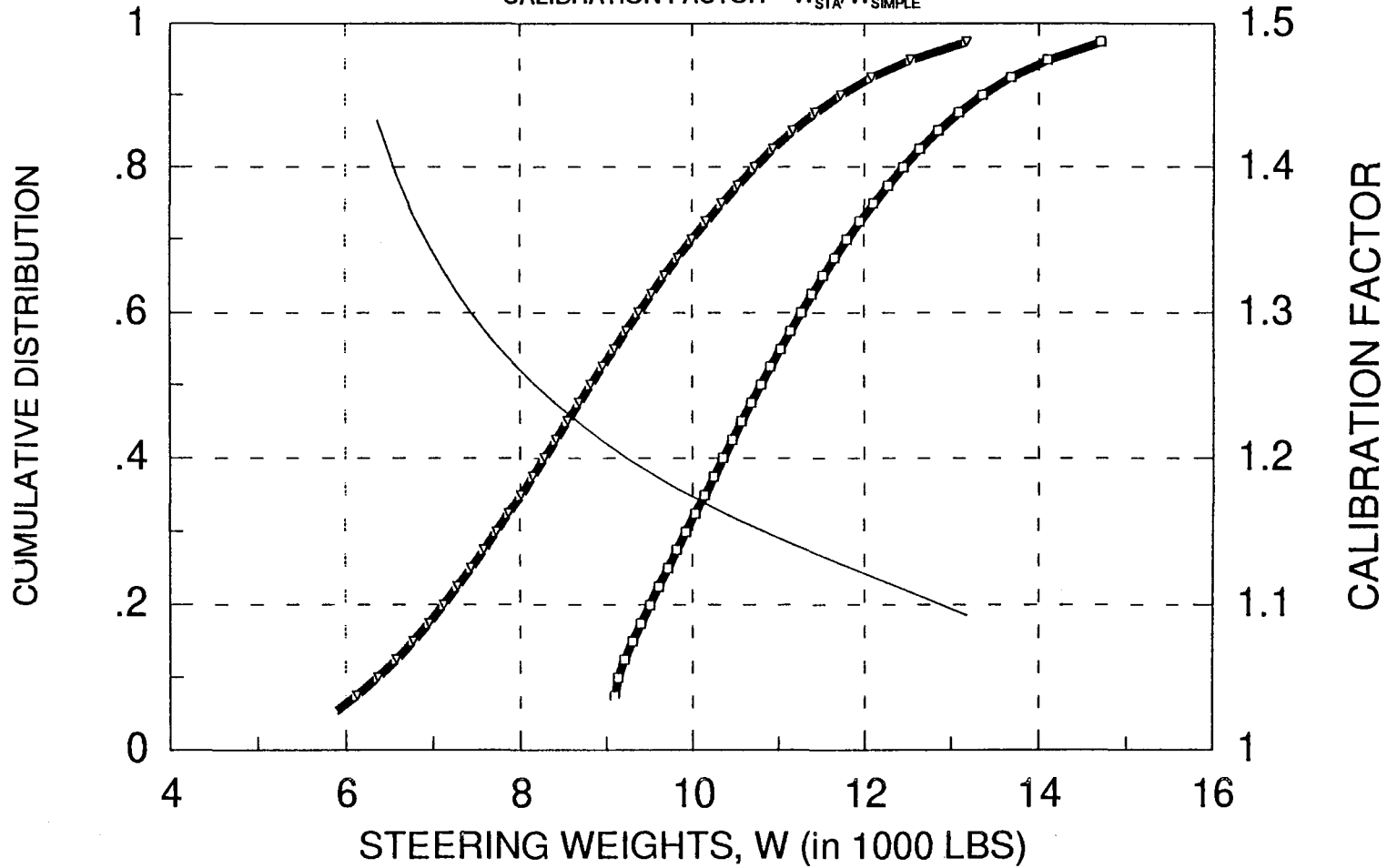
**Figure 18. Steering Axle Weight Distribution for Weigh Station and PCC Piezoelectric Cable.**

**STEERING AXLE DISTRIBUTION (WEIGH STATION VS. BRIDGE SIMPLE)**

-□ - STATION:  $\text{LOG}(F) = 1.134 + 0.245 \cdot W + 0.087 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - SIMPLE:  $\text{LOG}(F) = 1.075 + 0.270 \cdot W + 0.055 \cdot W^2$  ( $R^2 = 0.97$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}} / W_{\text{SIMPLE}}$



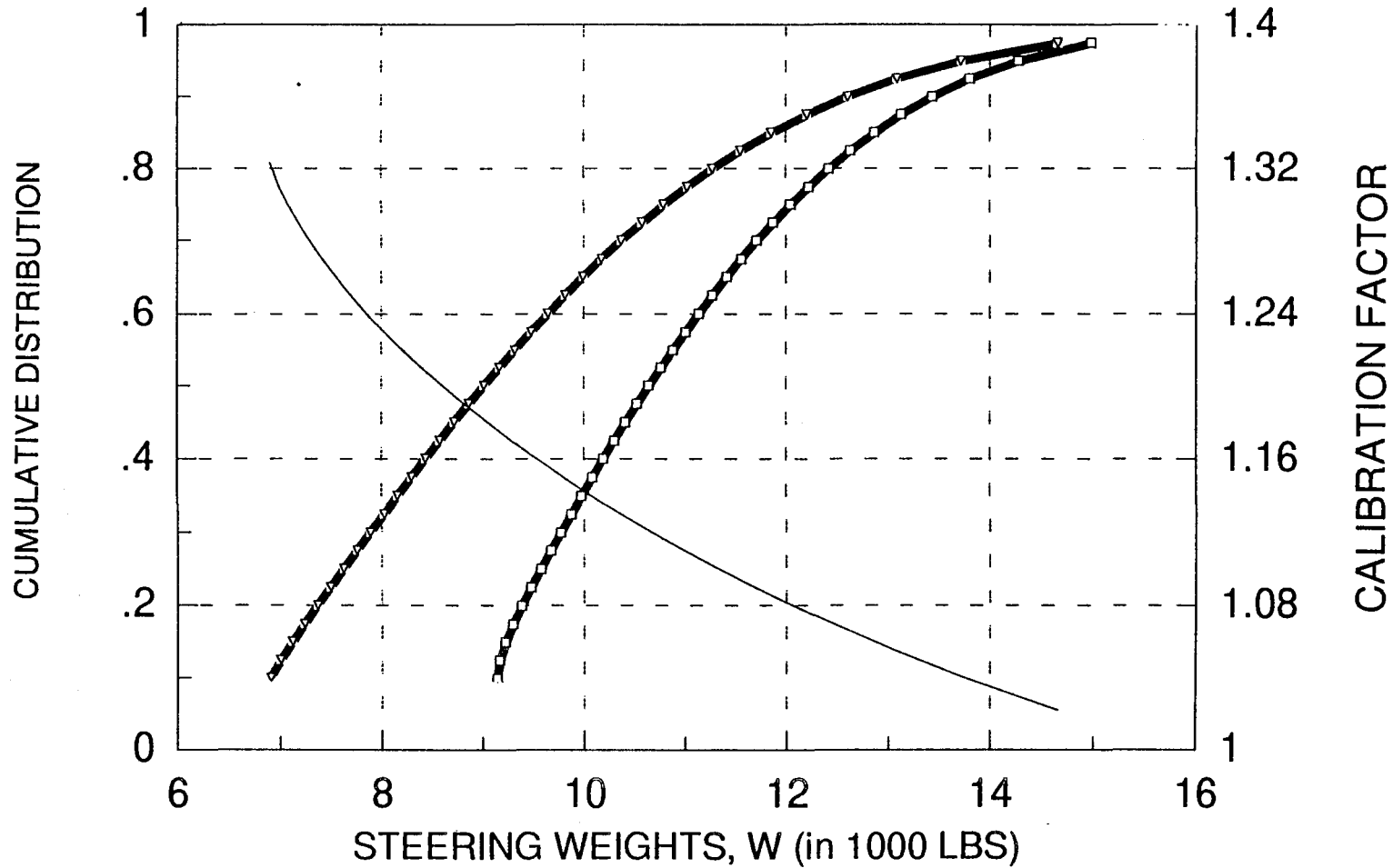
**Figure 19. Steering Axle Weight Distribution for Weigh Station and Bridge WIM (Simple Span).**

**STEERING AXLE DISTRIBUTION (WEIGH STATION VS. BRIDGE CONT.)**

-□ - STATION:  $\text{LOG}(F) = 1.134 + 0.245 \cdot W + 0.087 \cdot W^2$  ( $R^2 = 0.93$ )

-▽ - CONT:  $\text{LOG}(F) = 1.108 + 0.343 \cdot W + 0.108 \cdot W^2$  ( $R^2 = 0.98$ )

-- CALIBRATION FACTOR =  $W_{\text{STA}} / W_{\text{CONT}}$



**Figure 20. Steering Axle Weight Distribution for Weigh Station and Bridge WIM (Continuous).**

# AUG 93 WIM TESTS - WIM SYSTEM NO. 2

## COMPARISON OF DYNAMIC -vs- STATIC GROSSWEIGHT DATA

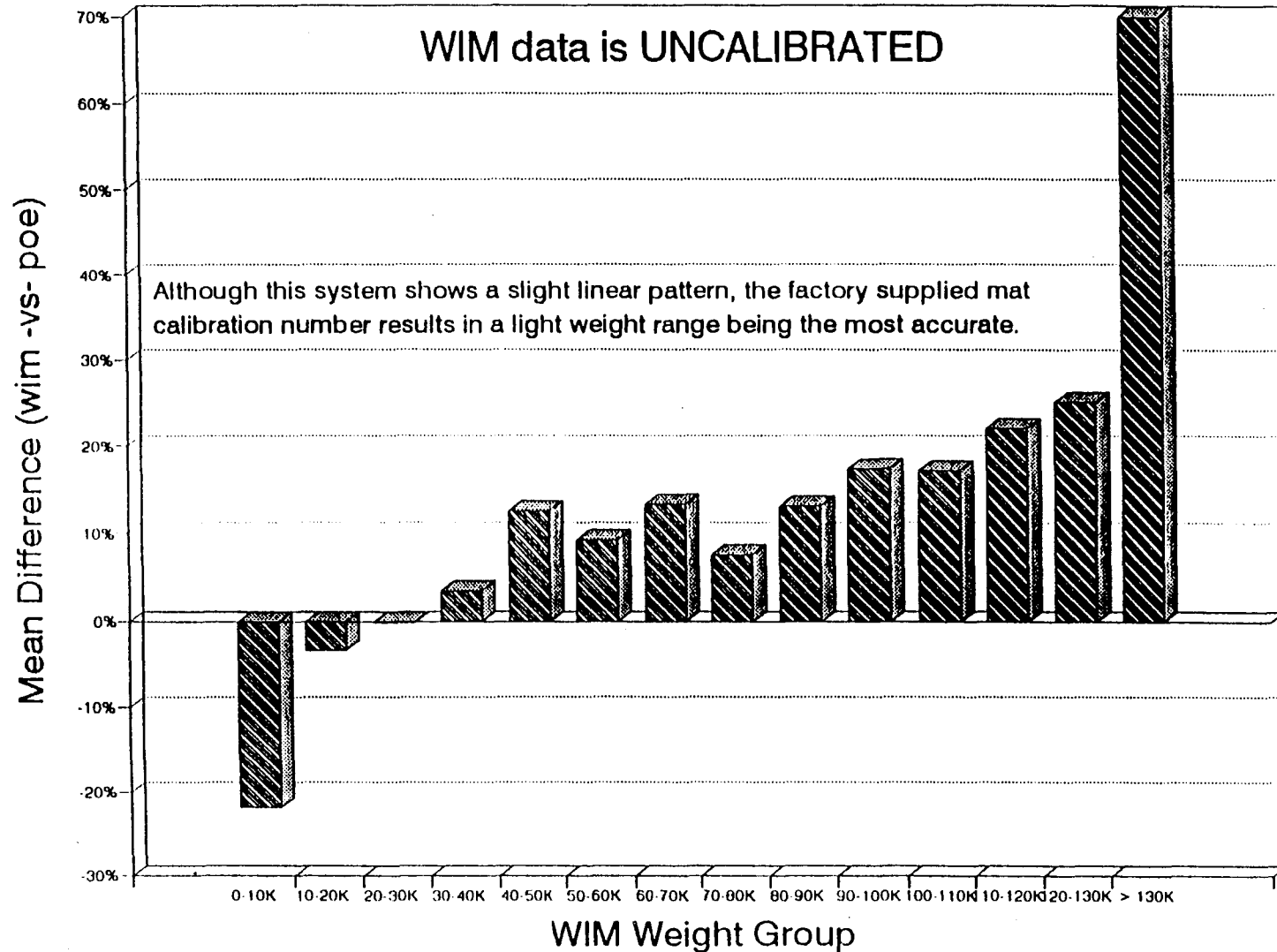
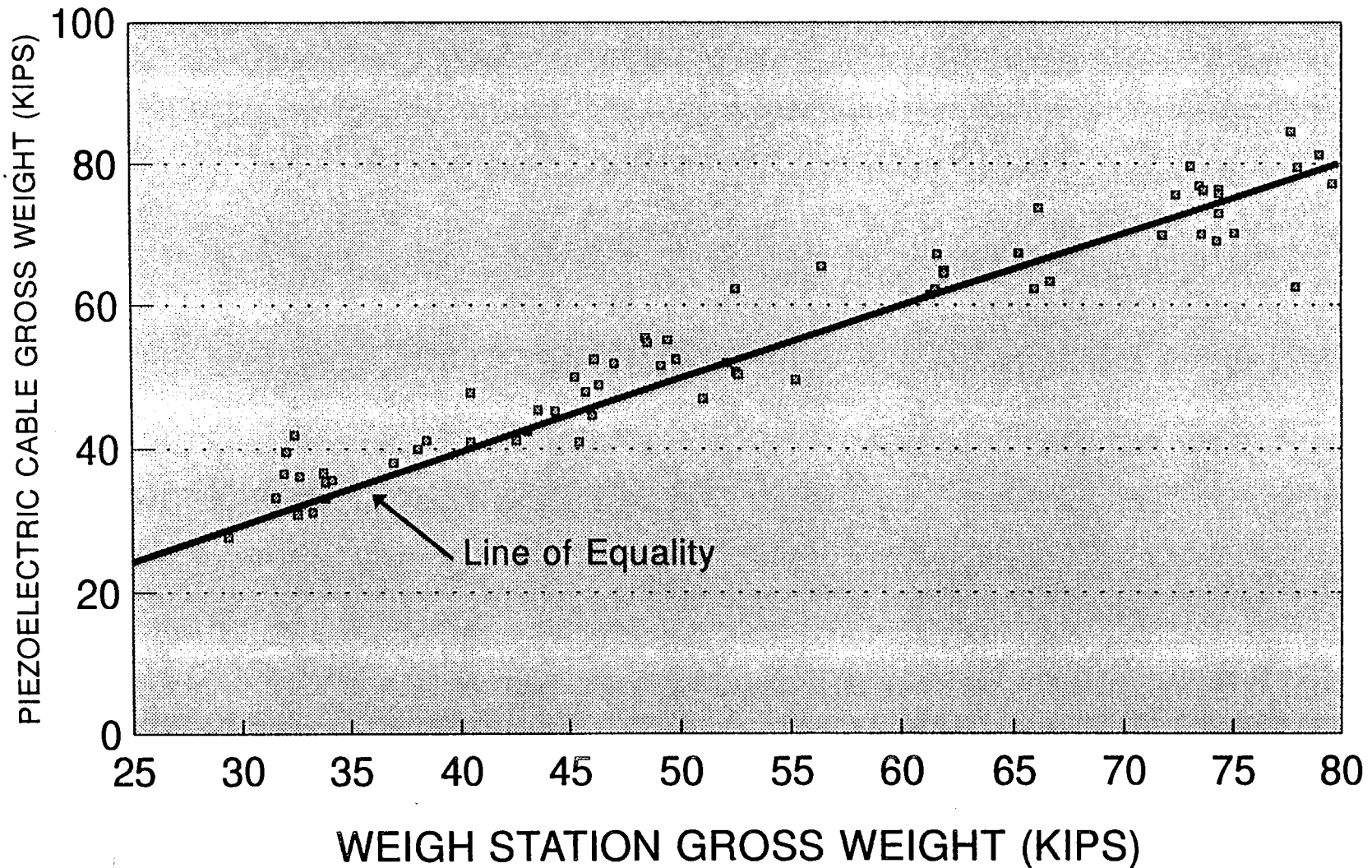


Figure 21. Multiple Point Calibration Factors (from Reference 14).

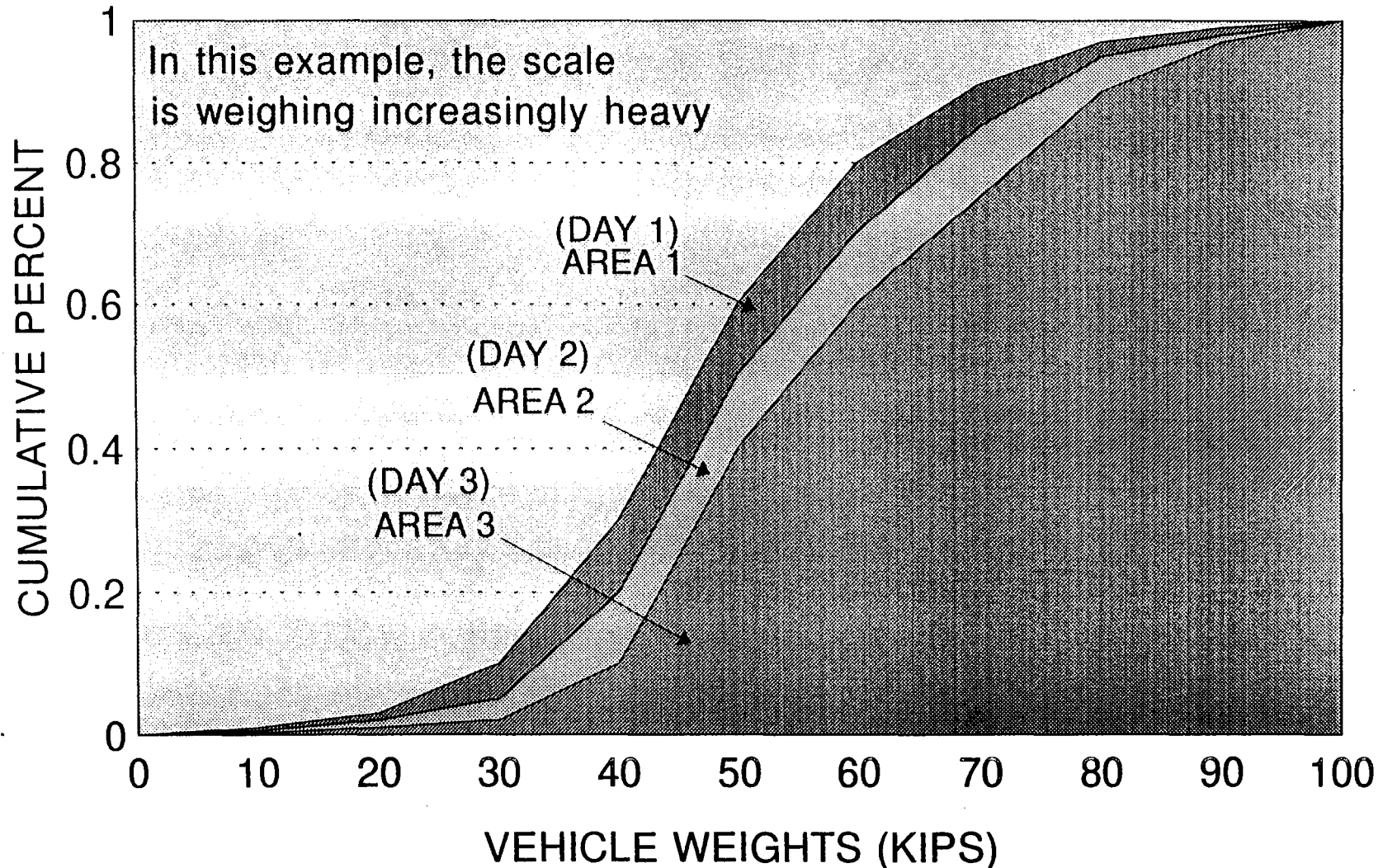
# WEIGH STATION vs. PCC PIEZOELECTRIC CABLE (FROM CONTINUOUS CALIBRATION FUNCTION)



**Figure 22. Gross Weights for PCC Piezoelectric Cable and Weigh Station Using Continuous Calibration Function.**



# CHECKING WIM DRIFT BY CHANGING AREAS UNDER THE DISTRIBUTION CURVE



**Figure 23. Checking WIM Drift by Changing Areas Under Distribution Curve.**

# CHECKING RANDOM ERRORS BY INCREASING STANDARD DEVIATION

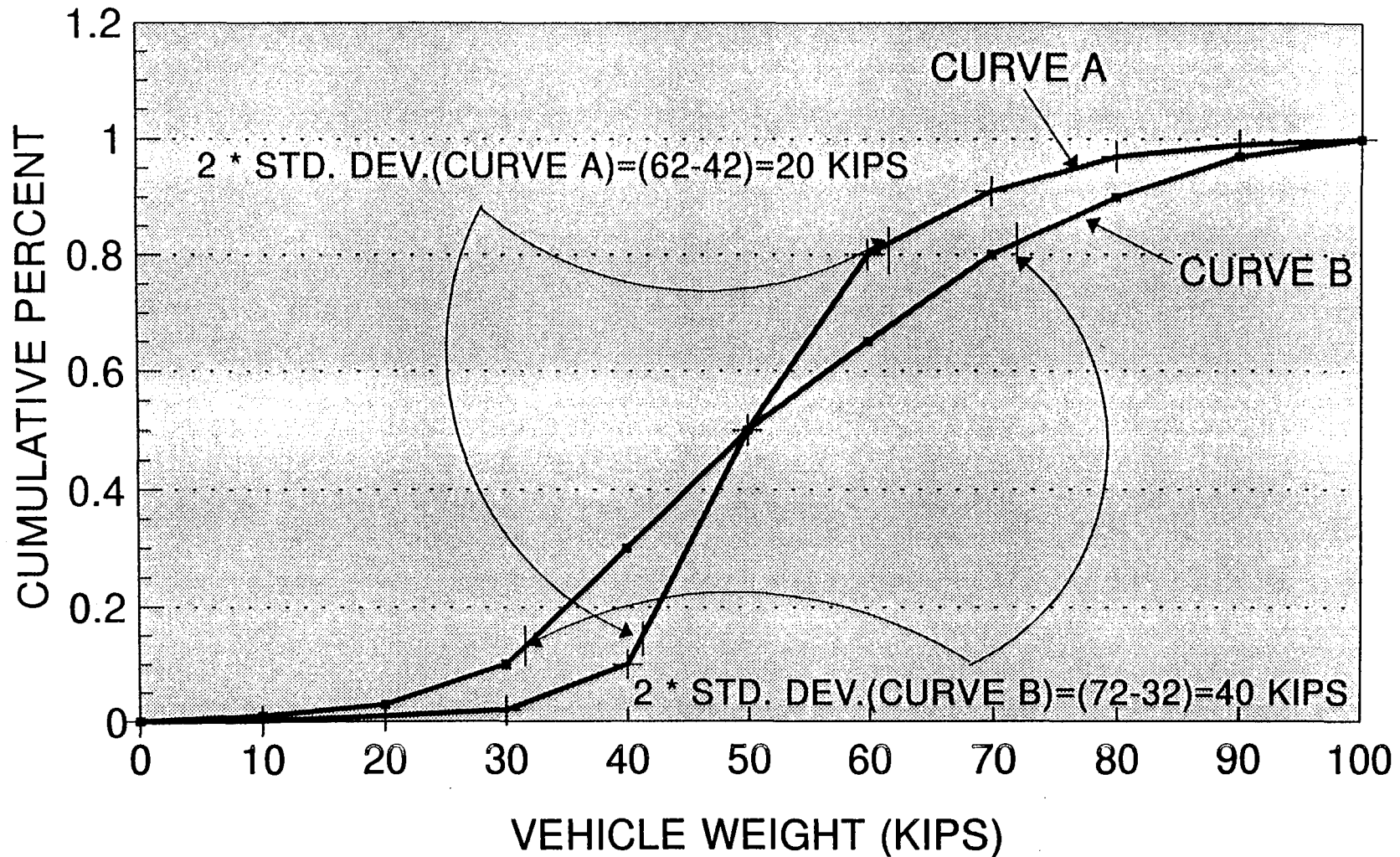
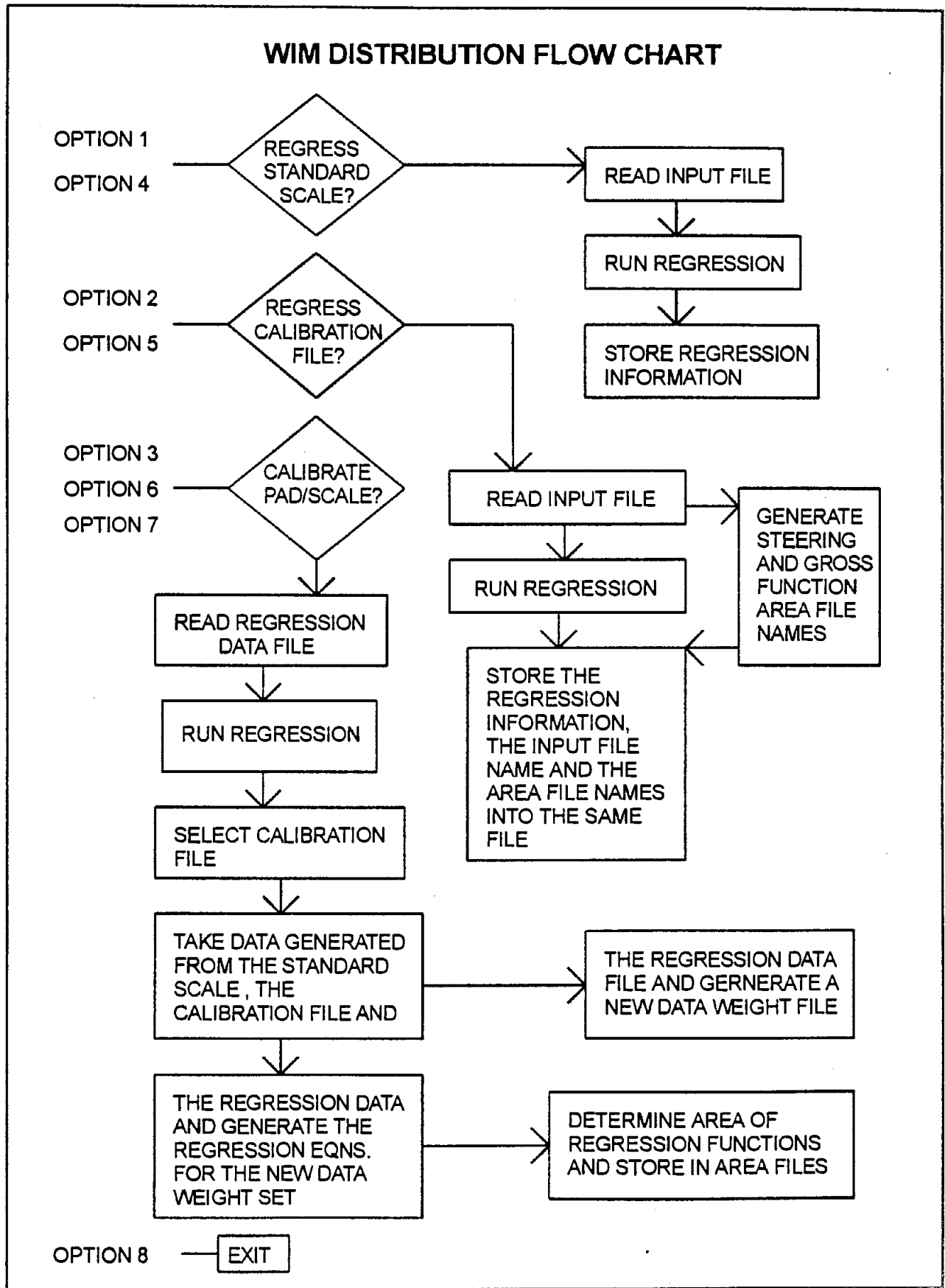


Figure 24. Checking Random Errors by Increasing Standard Deviation.



**Figure 25. Generalized Flow Chart for "WIMBOTH".**



**APPENDIX A**

**USER'S MANUAL**

**COMPUTER PROGRAM**  
**"WIMBOTH"**



**WEIGH-IN-MOTION  
WEIGHT DISTRIBUTION PROGRAM  
"WIMBOTH"**

Kentucky Transportation Center

By:

Patrick McCamish, Programmer/Analyst





## USING THE WIM DATA WEIGHT DISTRIBUTION PROGRAM

### BASIC OVERVIEW

This program's menu will give the user a choice of eight options grouped into two distinct phases. Both phases are used to calibrate scales and pads according to a chosen weigh station. The method of calibration in Phase One is to take data files for the pad chosen for calibration and the weigh station from the same traffic stream. Enter the weigh station's data file for Option One in the main menu and the pad's data file for Option Two. All following data files derived from traffic streams for that particular pad may now be calibrated to the weigh station by entering it under Option Three. For scales that cannot be used in conjunction with the weigh station, there is another way of calibrating them according to the weigh station. Phase Two is used for this process. While the data from Options One and Two will be kept, that pad will be taken and used in conjunction on the same traffic stream with the scale that needs to be calibrated according to the weigh station. The pad's new data file will be entered under Option Four as the standard file and the scale's data file will be entered under option five as the calibration file. All following data files derived from traffic streams for that particular scale may now be calibrated to the weigh station by first entering it under Option Six. Then take the output file from Step Six and enter that file under Option Seven (the calibration file the user selects and the data file in Option Four must both be derived from the same pad. Note: Option Seven is essentially the same as Option Two). The output file from Option Seven will be a calibrated file for the scale according to the weigh station. Select Option Eight to exit the program.

### RUNNING THE PROGRAM

To get started, type

"wimboth"

and hit

<Enter>.

At the introductory screen hit

<Enter>

then chose the option from the main menu.

## **OPTION ONE**

"1. DO THE STANDARD FILE FOR THE WEIGH STATION."

Press the

<1>

key. The prompt,

"ENTER THE STANDARD FILE FOR THE WEIGH STATION :"

appears on the screen. Enter the appropriate file name and hit

<Enter>.

You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

with the names of the output files displayed on the screen. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

## **OPTION TWO**

"2. DO THE CALIBRATION FILE FOR THE CALIBRATION PAD."

Press the

<2>

key. The prompt,

"ENTER THE CALIBRATION FILE FOR THE CALIBRATION PAD :"

appears on the screen. Type the full name of the pad data file from the traffic stream used in conjunction with the weigh station and hit

<Enter>.

You will then see,

"THE NAME FOR THE FILE FOR THE AREA FOR  
STEERING IS:  
#####.STR

THE NAME FOR THE FILE FOR THE AREA FOR  
GROSS WEIGHT IS:  
#####.GRS"

These are the names of the area files. These files will always have the same name as the calibration file that they correspond to, but the extension for the steering weight area file will be

".STR"

and the extension for the gross weight area file will be

".GRS"

Hit

<Enter>

to continue. You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

with the names of the output files displayed on the screen. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

### **OPTION THREE**

"3. CALIBRATE THE INPUT FILE FROM THE CALIBRATION PAD."

Press the

<3>

key. The prompt,

"ENTER THE INPUT FILE FROM THE CALIBRATION PAD :"

appears on the screen. Type the full name of the pad data file to be calibrated and hit

<Enter>

You will be prompted with

"OUTPUT NAME OF THE CORRECTED DATA SET (CANNOT BE THE SAME AS THE INPUT FILE)."

Type the name of the output using the first part of the input file, but change the extension to

".pad"

and hit

<Enter>

You should see

"WIMDIST PROGRAM IS RUNNING"

Next you should see

"ENTER THE NAME OF YOUR CALIBRATION FILE. THESE ARE YOUR SELECTIONS FROM CALIPAD.OUT."

and a list of the calibration files (if you have more than eighteen calibration files to choose from, then you will also see

"PLEASE ENTER FOR MORE IN THE LIST"

hit

<Enter>

to see the rest of the list). Type the name of the calibration file that was used for your present data set's pad and hit

<Enter>.

You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

and the list of output files. You will see warnings in the top left corner of the screen if this is your first usage of a particular calibration data file. If this is not the first usage, then you may need to check the pad for drift. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

#### **OPTION FOUR**

"1. DO THE STANDARD FILE FOR THE CALIBRATION PAD."

Press the

<4>

key. The prompt,

"ENTER THE STANDARD FILE FOR THE CALIBRATION PAD :"

appears on the screen. Enter the appropriate file name and hit

<Enter>.

You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

with the names of the output files displayed on the screen. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

## **OPTION FIVE**

"2. DO THE CALIBRATION FILE FOR THE SECOND SCALE."

Press the

<5>

key. The prompt,

"ENTER THE CALIBRATION FILE FOR THE SECOND SCALE :"

appears on the screen. Type the full name of the scale data file from the traffic stream used in conjunction with the pad (this is the same pad that was previously used in conjunction with the weigh station) and hit

<Enter>.

You will then see,

"THE NAME FOR THE FILE FOR THE AREA FOR  
STEERING IS:  
#####.STR

THE NAME FOR THE FILE FOR THE AREA FOR  
GROSS WEIGHT IS:  
#####.GRS"

These are the names of the area files. These files will always have the same name as the calibration file that they correspond to, but the extension for the steering weight area file will be

".STR"

and the extension for the gross weight area file will be

".GRS"

Hit

<Enter>

to continue. You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

with the names of the output files displayed on the screen. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

## OPTION SIX

"3. CALIBRATE THE INPUT FILE FROM THE SECOND SCALE."

Press the

<6>

key. The prompt,

"ENTER THE INPUT FILE FROM THE SECOND SCALE :"

appears on the screen. Type the full name of the pad data file to be calibrated and hit

<Enter>

You will be prompted with

"OUTPUT NAME OF THE CORRECTED DATA SET (CANNOT BE THE SAME AS THE INPUT FILE)."

Type the name of the output using the first part of the input file only change the extension to

".mod"

and hit

<Enter>

You should see

"WIMDIST PROGRAM IS RUNNING"

Next you should see

"ENTER THE NAME OF YOUR CALIBRATION FILE. THESE ARE YOUR SELECTIONS FROM CALIBRAT.OUT."

and a list of the calibration files (If you have more than eighteen calibration files to choose from, then you will also see

"PLEASE ENTER FOR MORE IN THE LIST"

hit

<Enter>

to see the rest of the list). Type the name of the calibration file that was used for your present data set's pad and hit

<Enter>.

You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

and the list of output files. You will see warnings in the top left corner of the screen if this is your first usage of a particular calibration data file. If this is not the first usage, then you may need to check the pad for drift. Hit



<Enter>

to exit the program or

"C" or "c"

to continue the program.

## **OPTION SEVEN**

"3. CALIBRATE THE OUTPUT FILE FROM PHASE TWO."

Press the

<7>

key. The prompt,

"ENTER THE OUTPUT FILE FROM PHASE TWO :"

appears on the screen. Type the full name of the pad data file to be calibrated and hit

<Enter>

You will be prompted with

"OUTPUT NAME OF THE CORRECTED DATA SET (CANNOT BE THE SAME AS THE INPUT FILE)."

Type the name of the output using the first part of the input file, but change the extension to

".las"

and hit

<Enter>

You should see

"WIMDIST PROGRAM IS RUNNING"

Next you should see

"ENTER THE NAME OF YOUR CALIBRATION FILE. THESE ARE YOUR SELECTIONS FROM CALIBRAT.OUT."

and a list of the calibration files (if you have more than eighteen calibration files to choose from, then you will also see

"PLEASE ENTER FOR MORE IN THE LIST"

hit

<Enter>

to see the rest of the list). Type the name of the calibration file that was used for your present data set's pad and hit

<Enter>.

You should see

"WIMDIST PROGRAM IS RUNNING"

and then finally

"JOB COMPLETED"

and the list of output files. You will see warnings in the top left corner of the screen if this is your first usage of a particular calibration data file. If this is not the first usage, then you may need to check the pad for drift. Hit

<Enter>

to exit the program or

"C" or "c"

to continue the program.

## **OPTION EIGHT**

"8. EXIT THE PROGRAM"

Press the

<8>

key to exit the program.

## **OUTPUT FILES - Names and Definitions**

### **OPTION 1**

STPDTAIL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weight less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the standard data file.

STPDPAD.OUT - This file contains the standard data file's regression function for the steering (third line) and the gross weights (fourth line) and their displacement data points (first data column is for steering and second data column is for gross).

### **OPTION 2**

PADCAL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the calibrated data file.

CALIPAD.OUT - This file contains the calibration data file's regression function for the steering and the gross weights and their displacement data points (first data column is for steering and second data column is for gross) for all of the calibration data file's that have been run (output of all STAGE 2 calibration file regressions).

### **OPTION 3 (Names and Definitions given in the order of appearance from under "OUTPUT FILES")**

#####.pad - Output filename of the calibrated file.

#####.STR - This file contains the area data of the steering weight function from the calibrated files that go with its calibration data file (ex.: If you take data files from the same traffic stream for a weight station #4 and a pad A, then the standard file is from weigh station #4 and the calibration data file is from pad A (call the calibration data file, "PADA1.DAT"). From a second traffic stream, take one data file for the pad A independent of the weight station (call this data file, "PADA2.DAT"). In order to calibrate PADA2.DAT according to the weigh station, the data derived from the weight station is divided by the data derived from PADA1.DAT and multiplied by the data derived from PADA2.DAT written to the user's choice of an output file. PADA1.STR will be the name of the file in which the area data for the steering will be kept. In other words, PADA1.DAT is the calibration data file for PADA2.DAT).

#####.GRS - This file contains the area data of the gross weight function from the calibrated files that go with its calibration data file (same explanation as for #####.STR).

PADTAIL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the input data file.

PADSOL.OUT - This file contains the input data file's regression function for the steering (third line) and the gross weights (fourth line) and their displacement data points (first data column is for steering and second data column is for gross).

#### **OPTION 4**

STANTAIL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the standard data file.

STANDARD.OUT - This file contains the standard data file's regression function for the steering (third line) and the gross weights (fourth line) and their displacement data points (first data column is for steering and second data column is for gross).

#### **OPTION 5**

WTVCAL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the calibrated data file.

CALIBRAT.OUT - This file contains the calibration data file's regression function for the steering and the gross weights and their displacement data points (first data column is for steering and second data column is for gross) for all of the calibration data file's that have been run (output of all STAGE 2 calibration file regressions).

#### **OPTION 6 (Names and Definitions given in the order of appearance from under "OUTPUT FILES")**

#####.mod - Output filename of the calibrated file.

#####.STR - This file contains the area data of the steering weight function from the calibrated files that go with its calibration data file (ex.: If you take data files from the same traffic stream for a weigh station #4 and a pad A, then the standard file is from weigh station #4 and the calibration data file is from pad A (call the calibration data file, "PADA1.DAT"). From a second traffic stream, take one data file for the pad A independent of the weigh station (call this data file,

"PADA2.DAT"). In order to calibrate PADA2.DAT according to the weigh station, the data derived from the weigh station is divided by the data derived from PADA1.DAT and multiplied by the data derived from PADA2.DAT written to the user's choice of an output file. PADA1.STR will be the name of the file in which the area data for the steering will be kept. In other words, PADA1.DAT is the calibration data file for PADA2.DAT).

#####.GRS - This file contains the area data of the gross weight function from the calibrated files that go with its calibration data file (same explanation as for #####.STR).

NEXTTAIL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the input data file.

NEXTSOL.OUT - This file contains the input data file's regression function for the steering (third line) and the gross weights (fourth line) and their displacement data points (first data column is for steering and second data column is for gross).

#### **OPTION 7 (Names and Definitions given in the order of appearance from under "OUTPUT FILES")**

#####.las - Output filename of the calibrated file.

#####.STR - This file contains the area data of the steering weight function from the calibrated files that go with its calibration data file (ex.: If you take data files from the same traffic stream for a weigh station #4 and a pad A, then the standard file is from weigh station #4 and the calibration data file is from pad A (call the calibration data file, "PADA1.DAT"). From a second traffic stream, take one data file for the pad A independent of the weight station (call this data file, "PADA2.DAT"). In order to calibrate PADA2.DAT according to the weigh station, the data derived from the weight station are divided by the data derived from PADA1.DAT and multiplied by the data derived from PADA2.DAT written to the user's choice of an output file. PADA1.STR will be the name of the file in which the area data for the steering will be kept. In other words, PADA1.DAT is the calibration data file for PADA2.DAT).

#####.GRS - This file contains the area data of the gross weight function from the calibrated files that go with its calibration data file (same explanation as for #####.STR).

PADTAIL.OUT - This file contains the data concerning the weight bins (first and third columns with a scale of \*1000) and the number of vehicles that weigh less than or equal to the corresponding weight bin (second column goes with the first column and the fourth column goes with the third column) for the input data file.

PADSOL.OUT - This file contains the input data file's regression function for the steering (third line) and the gross weights (fourth line) and their displacement data points (first data column is for

steering and second data column is for gross).

### **RESTRICTIONS TO NAMING CONVENTIONS**

Follows the normal DOS naming conventions except that there must be no less than five characters preceding the extension.

### **PURPOSE OF THE AREA FILES**

The area files are for checking drift in the pads. If, when plotted in a scatter diagram, the graph shows a randomized displacement of the area points, then there should be no immediate problem in drift. However, if there is a steady pattern of increase or decrease in the placement of the points, then a problem of drift should be suspected. If you receive a warning anytime in OPTION 3, 6 or 7 and you have more than one area point in the area files, then a problem of drift should be suspected.