Application Distance Photometry

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Introduction

Due to the relatively low ceiling heights existing in many office buildings, indirect luminaires must often be mounted close to the ceiling. This need for close mounting distances (short suspension lengths) has led to the development of indirect fluorescent luminaires having highly efficient, inverted, batwing distributions. Specular (mirrorlike) reflectors and specially designed lenses are important elements of such luminaires. The unique nature of such optical systems reduces the accuracy of discretizing techniques normally used by computer programs when calculating illuminance close to the luminaire. Because far-field photometry provides no information about luminaire luminances, discretizing techniques must assume that the luminaire is planer and of perfectly uniform luminance. They also assume that each element of the luminaire has the same luminous intensity distribution as each other element. These assumptions usually work for luminaires located several feet from the surface they are lighting. However it will be shown here that discretizing techniques coupled with far field photometric data do not yield sufficiently accurate results when indirect luminaires are mounted close (less than 30 inches) to the ceiling.

This paper was initiated because one of the authors (Brass) noticed that mirror type optical systems deviated significantly from the usual discretizing assumptions. This occurs because virtual images produced by reflectors or lenses are greatly displaced from the assumed light center and even the physical extents of the luminaire (**Figure A**). Furthermore, these images appear and disappear in a way that defies simplifying assumptions.

Application Distance Photometry is proposed as a solution to these problems. Equivalent luminous intensity data obtained by application distance photometry produce accurate results when used by any computer program (or hand method) capable of solving the inverse square law.

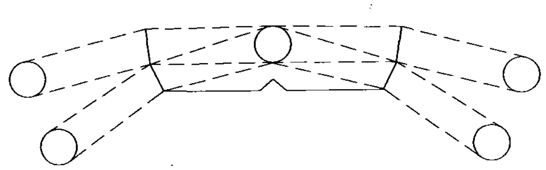

Figure A—Virtual lamp images displaced by reflectors.

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Background

Far field photometry evolved from the requirements of point source calculations using the inverse square law:

$$E = (I / d^2) * \cos \theta \qquad (1)$$

For this equation to be accurate, the light source (luminaire) must be a point source. It has been found that for most luminaires, the point source requirement can be broadened to include luminaires whose maximum dimension is less than one-fifth of the distance (d) between the luminaire and the point being calculated.

Conventional candela distributions are measured using **Equation 1** in reverse, namely:

$$I = E * d^2 / \cos \theta \qquad (2)$$

On most of the goniophotometers in use today, θ is fixed at 90 degrees (causing the cosine to be 1.0) and distance d is fixed. This allows the luminous intensity (I) to be directly proportional to the measured illuminance (E). Photometers measure illuminance from which intensity is calculated. As with illuminance calculations, the luminaire may be no more than one-fifth of the photometer's test distance.

When large luminaires are close to the surfaces they are lighting, discretizing assumptions often break down and lead to inaccurate calculations.

Attempts have been made at photometering a luminaire in small (discrete) portions and representing the luminaire as a series of subdistributions (one for each portion).[1] This technique, while successful, has never found its way into commercial use because of its complexity and the thermal instability of fluorescent luminaires when partitioning masks are applied. Application Distance Photometry is another solution to this problem.

The process

With an indirect luminaire mounted close to the ceiling, illuminances are measured on the ceiling at specific locations. From these illuminances effective luminous intensities are calculated (**Equation 2**). This process is similar to conventional far field photometry except that distance d and angle θ change with each location. In addition, the effective luminous intensity data are only applicable for point source calculations when the luminaire is at the mounting distance as tested. Application distance photometric

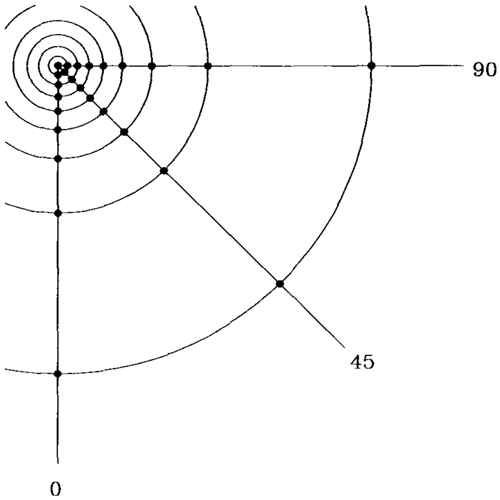


Figure B—Intersection of type A spherical coordinates with ceiling plane.

reports must be produced for each anticipated suspension length.

To construct the effective candela distribution in a standard form such as the IES Photometric File Format, measurements are made at locations defined by the intersection of the ceiling plane with projections of standard increments of the type A spherical coordinate system (**Figure B**). For simplicity, horizontal illuminances (facing down) are measured with a photometer known to have excellent cosine correction (**Figure C**). The alternative is to keep the photocell aimed directly at the center of the luminaire, requiring substantially more mechanical complexity.

Geometry makes it impossible to measure illuminance at an elevation of 90 degrees and space limitations may prohibit measurements at 100 or 110 degrees. In this case, application distance intensities can be merged with a conventional far field distribution. For large luminaires it may be prudent to model the upward and downward components as separate luminaires.

Once Application Distance Photometric data are cast in the form of an IES file, any computer program that can solve the inverse square law (**Equation 1**) can calculate ceiling illuminances with near perfect accuracy. The only real limit to accuracy is the interpolant.

Where near-field calculations with far-field photometry require descretization or integration over the entire (light emitting) surface area of the luminaire, application distance photometry does not. This is because application distance measurements already include the effects of the luminaire's relatively large surface area. As calculated effective intensity radiates from a point, luminaires calculated from application distance photometry are assumed to be point sources, even if they are not!

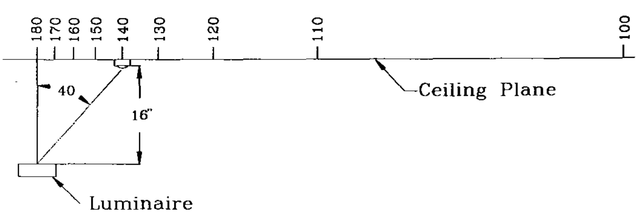


Figure C—Illuminance measurements on ceiling.

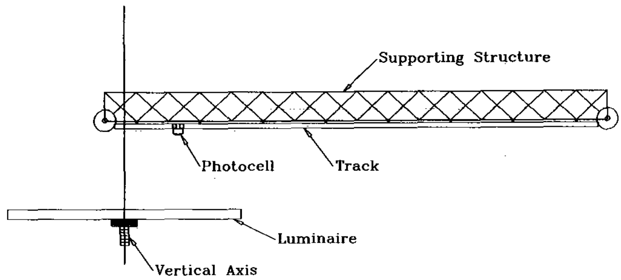


Figure D—Application distance photometer

Photometric testing

Figures D and **E** show what an application distance photometer might look like. A cosine corrected photocell is pulled on a carriage along a linear track. The track swings into position above the vertical axis of a conventional goniophotometer. The carriage is moved by a stepping-motor driven cable, controlled by the photometer's computer. The luminaire mount on the head of most photometers has a height adjustment which may be sufficient for a range of suspension lengths. If not, the track's height must be adjustable.

A normal, far-field relative photometric test is performed, then the application distance track is swung into place. Once adjusted to the appropriate height, the photocell travels along the track and measurements are recorded at the appropriate elevation angles. At the end of a traverse, the luminaire is rotated into position for the next plane and the process is repeated.

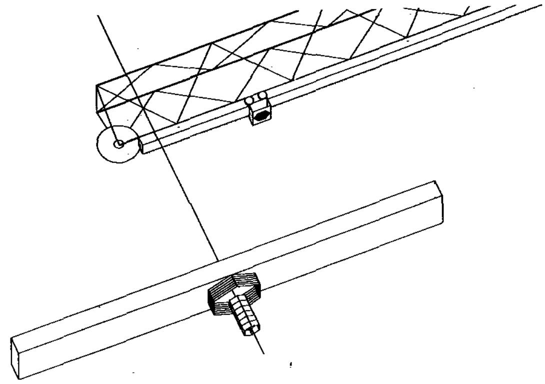


Figure E—Application distance photometer

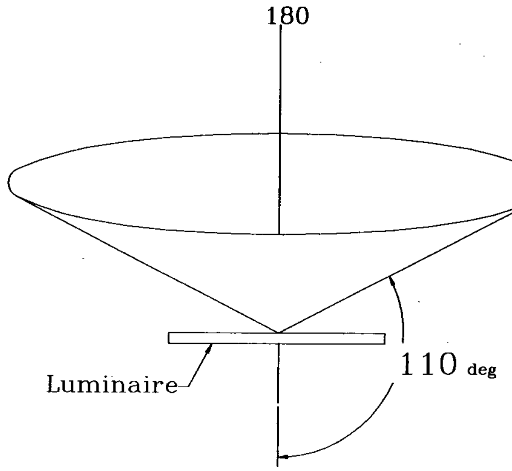


Figure F—110 degree cone

Application distance data are then merged with far-field data. To properly scale application distance intensities so that they are based on the same relative photometry as the far field measurements, a proportioning factor can be derived from the ratio of application distance to far-field flux in a cone from 180 degrees to the lowest elevation angle in the application distance measurements (**Figure F**).

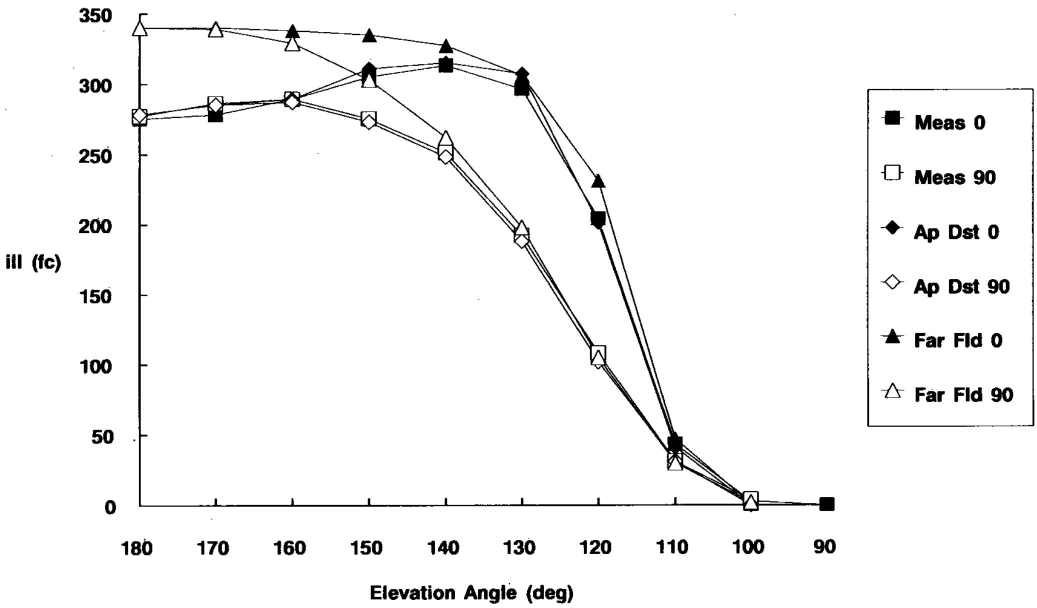
Results

A 6-inch wide by 4-ft long by 2-inch deep indirect luminaire with highly specular side reflectors and biax lamps was used to demonstrate the performance of calculations using application distance photometry. Calculations were made using a computer program that uses a Fourier series as its interpolant and integrates over the luminaire's surface area. Application distance calculations used application distance photometric data with luminaire dimensions of 0 by 0 (a point source). Far-field calculations used conventional photometric data and the luminaire's actual dimensions. To avoid interpolation errors, ceiling illuminance calculations were made at the candela distribution's data point projections onto the ceiling (**Figure B**).

For a suspension length of 12 inches, **Figure G** shows ceiling illuminances along the 0 degree (filled symbols) and 90 degree (outlined symbols) lateral planes at intersections with various vertical angles. Measured values are boxes. Application Distance calculated values are diamonds and far-field calculated values are triangles. Note that application distance values almost exactly follow the measured values while far-field values deviate more and more as the zenith (180 deg) is approached.

Percent error is plotted in **Figure H**. Application Distance errors are boxes and far field errors are diamonds. Again note the large errors in far field calculations as zenith is approached. Errors at low angles are due more to small differences in the low illuminances at those angles than to real computational differences.

Figure G—Ceiling illuminance, measured, far field, and application distance at 12 inches.



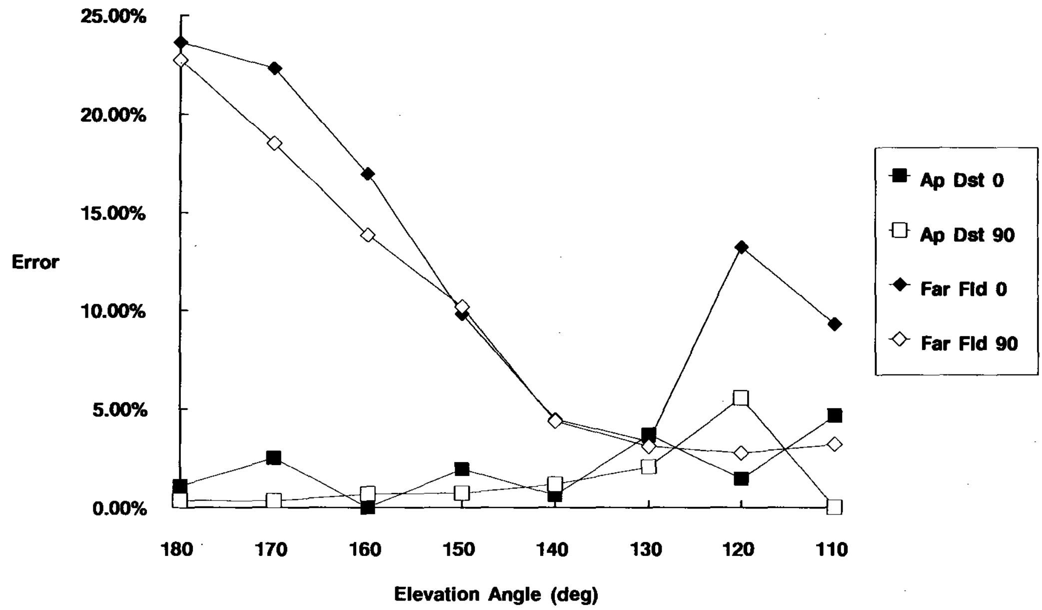


Figure H—Errors in far field and application distance photometry at 12 inches

Appendix A includes illuminance and error plots for the same luminaire at various suspension lengths. As suspension length increases, far-field errors diminish until, at a suspension length of 30 inches, far-field errors are insignificant. Tests of other luminaires would prove whether this 30-inch limit applies universally. Larger luminaires may require application distance photometry at greater distances.

Other considerations

The concepts described here for the application distance photometry of indirect luminaires can be adapted to task lights and wall mounted luminaires. For task lights, the track would be flipped over and placed below the photometer head.

Wall-mounted luminaires present a more complicated problem where they illuminate the wall. Type A spherical projections onto the wall require the photocell to move both laterally and vertically over the wall's surface. This requires an additional linear axis on the photometer.

Near the edge of a room, indirect luminaires often illuminate the walls. Under typical conditions, the luminaire is far enough from the wall, and the projection of its luminous area so small that merged far-field intensities suffice. When luminaires are close to a wall and have luminous sides, application distance intensities from ceiling and wall measurements could be merged.

While application distance photometry causes computer programs to yield accurate initial ceiling illuminances, the programs do not account for interreflections between the luminaire and the ceiling. This effect can be significant, particularly for large luminaires at short suspension lengths. By attaching ceiling panels to either side of the application distance photometer's track (**Figure I**), luminaire-ceiling interreflections can be incorporated in the photometric data. If the panel's reflectance is typical, the photometry will closely represent the interreflection affects even if the installed panel's reflectance differs slightly.

Application distance photometry will not account for the shadowing effects of indirect luminaires. This is a problem for the interreflection calculations, and cannot be measured with an application distance photometer.

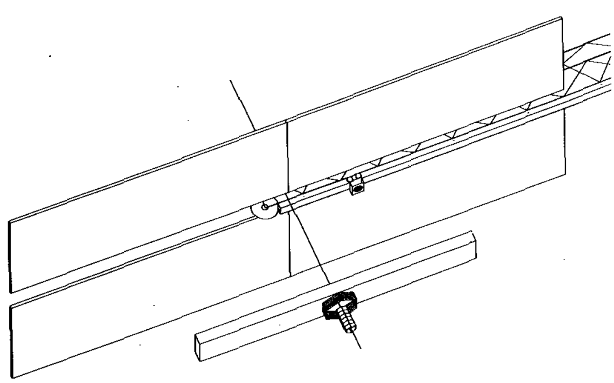


Figure I—Aplication distance photometer with reflective panels

Conclusions

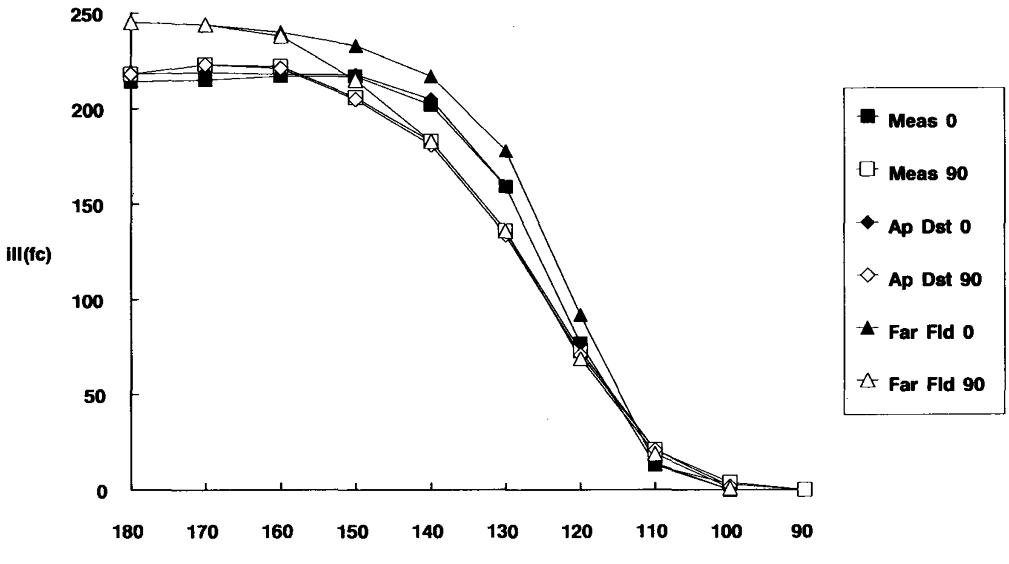
Application Distance Photometry promises to improve the accuracy of all computer programs when calculating indirect lighting. By casting the data into the standard IES format, this accuracy can be achieved without any modifications to the programs. Most automated goniophotometers can be adapted to perform application distance measurements with the addition of a linear track mounted photocell. Photometric software must be supplemented with control and data acquisition routines for the track, and data reduction and photometric file merge routines to build IES photometric files.

Reference

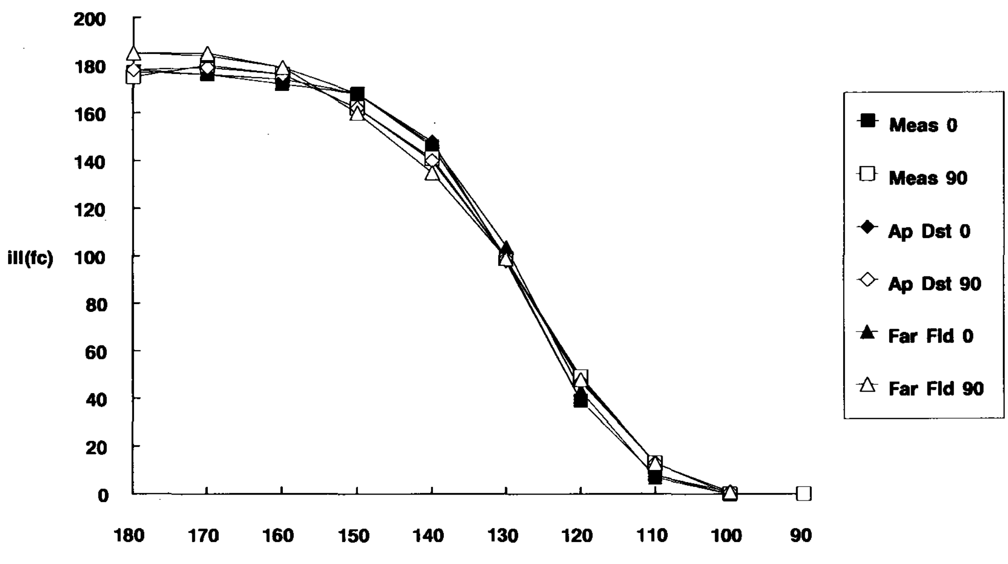
1. Lautzenheiser, T.; Weller, G. and Stannard, S. 1984. Photometry for Near Field Applications. *J of the IES*. 13 (no.2): 262–269.

Appendix A

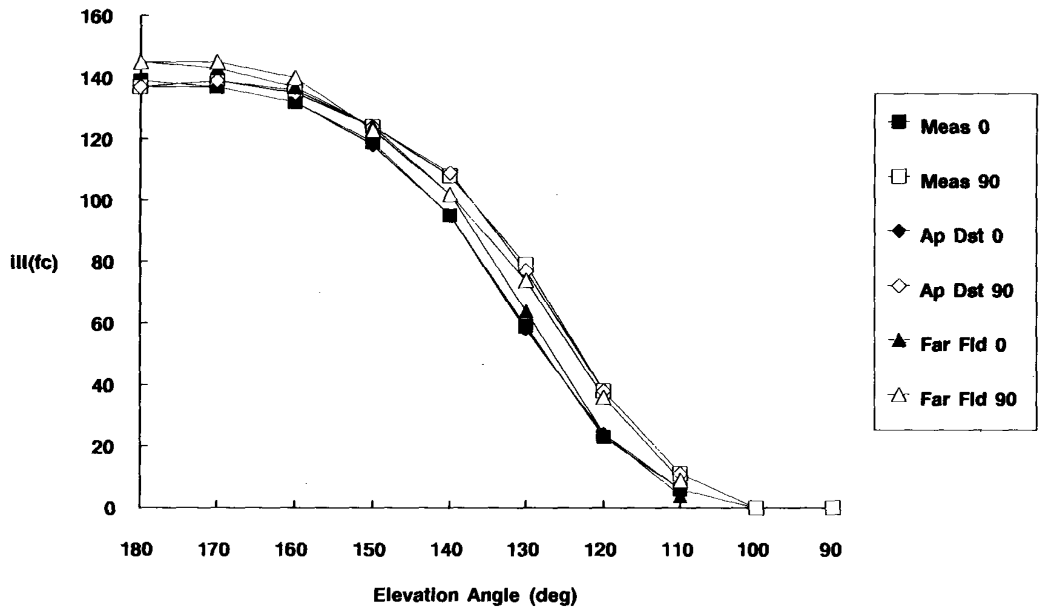
Ceiling illuminances and errors for suspension lengths from 12 to 30 inches.



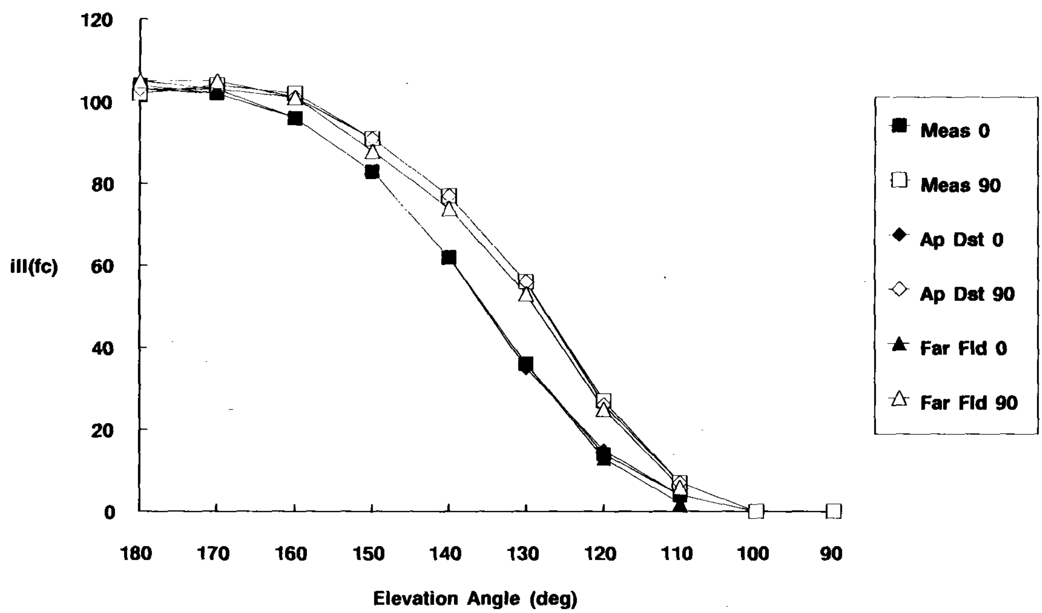
Ceiling Illuminance, Measured, Far Field and Application Distance at 16 in.



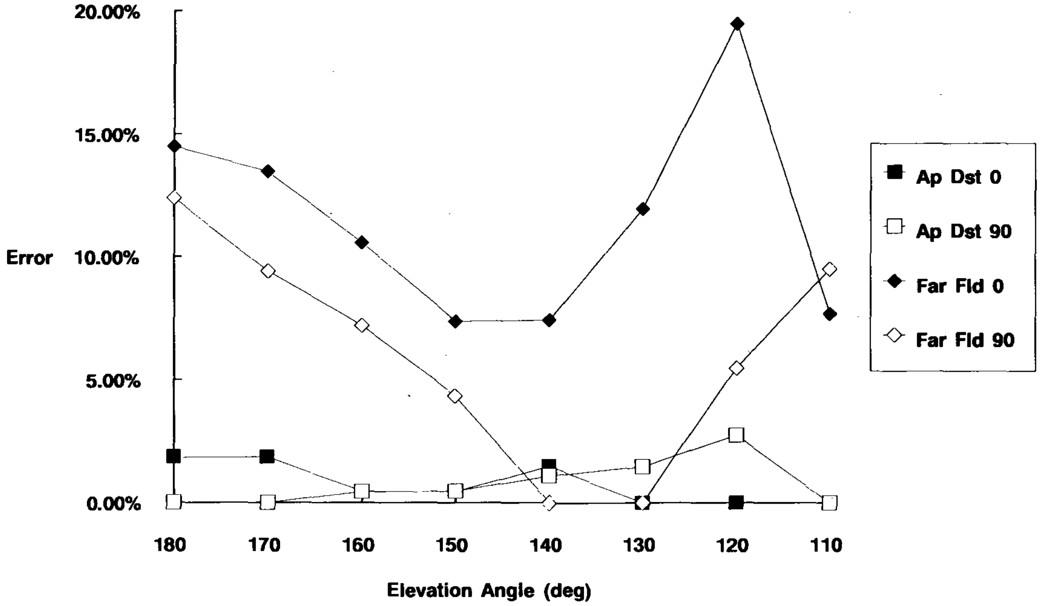
Ceiling Illuminance, Measured, Far Field and Application Distance at 20 in.



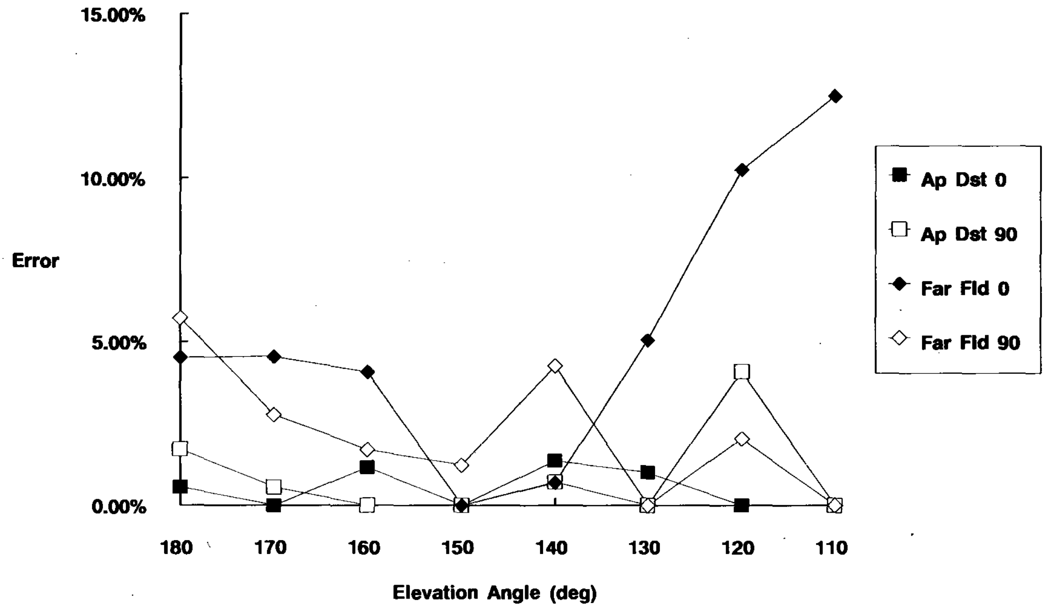
Ceiling Illuminance, Measured, Far Field and Application Distance at 24 in.



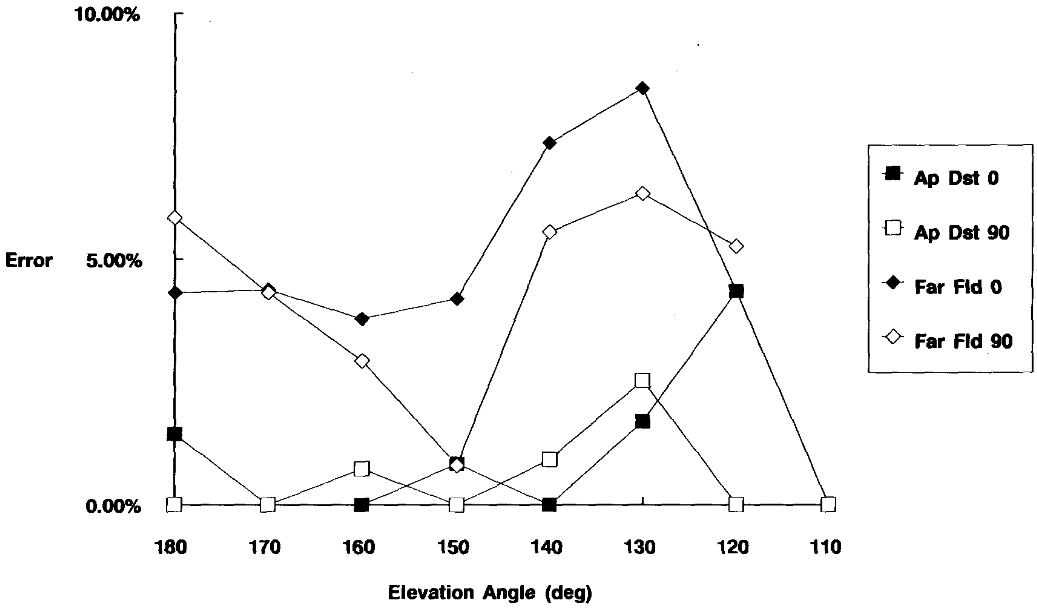
Ceiling Illuminance, Measured, Far Field and Application Distance at 30 in.



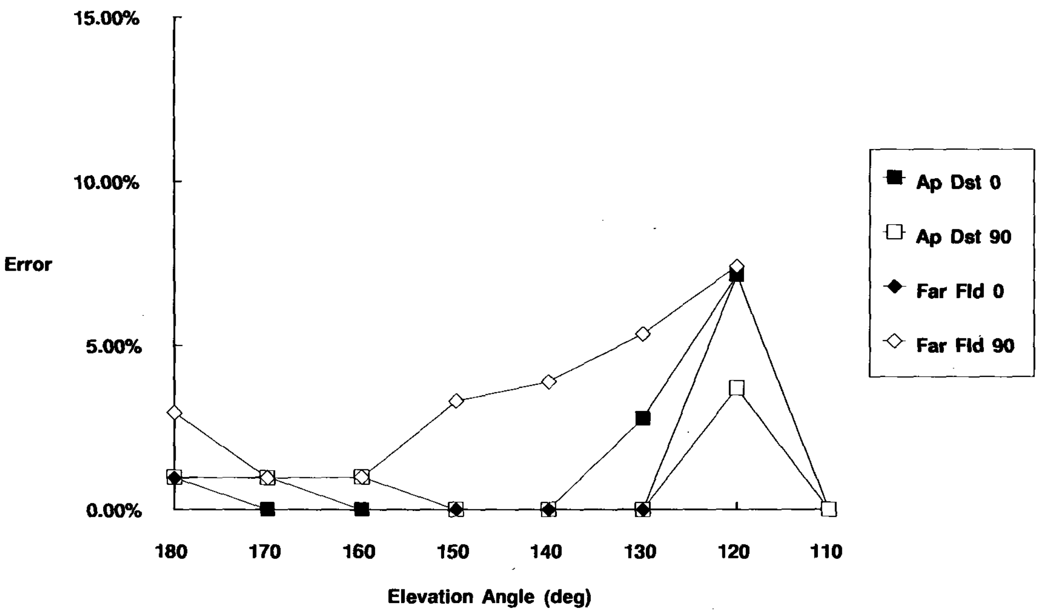
Errors in Far Field and Application Distance Photometry at 16 in.



Errors in Far Field and Application Distance Photometry at 20 in.



Errors in Far Field and Application Distance Photometry at 24 in.



Errors in Far Field and Application Distance Photometry at 30 in.