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REVISION OF EP-458: FIELD EVALUATION OF MICROIRRIGATION SYSTEMS

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Summary:
A draft revision of EP-458 Field Evaluation of Microirrigation Systems is presented. The rationale for the revisions is to improve the clarity of the document and to reduce the complexity of the evaluation. Key assumptions necessary for the statistical analysis were added to the document. Some of the statistical requirements of EP-458 may be neglected in a typical field evaluation. The importance of matching the statistical requirements has not been thoroughly investigated in this revision. This issue will likely require further technical discussions and perhaps further research.

Keywords:
Statistical analysis, drip irrigation, emitter flow, irrigation uniformity

Summary of Revisions to EP-458

A line-by-line examination of the revisions lies beyond the scope of this paper but a summary of revisions will be made. The proposed revision of EP-458 is added as Appendix A. Section numbers will be designated as new to refer to the proposed revised document or old to refer to the approved 1988 version of EP-458.

Old Section 1.1 and 1.2 -- Minor additions to enhance purpose and scope.

New Section 1.3 -- This section was added at the request of several SW-245 members who felt that SDI systems produced special difficulties for EP-458. (ie. sampling subsurface emitters). In addition, a recent publication by Sadler et al., (1995) indicates that excavating of emitters increased their flowrates by 3 to 4%, but probably would not affect uniformity calculations.

Old Section 2 -- Many definitions were removed because they are currently in S-526, Soil and Water Terminology. The removals are Old Section 2.1, 2.2, 2.5, 2.8, 2.14, 2.18, 2.20, 2.21, and 2.27.

Old Section 2 – Many definitions were removed because of the removal of Old Section 3.3 from the document which will be discussed later. Removals were Old Section 2.6, 2.17, 2.23, 2.24, 2.25, 2,26, and 2.28. The return of Old Section 3.3 to any future revisions of EP-458 would require significant changes to many of the removed definitions. This was a recognized problem at the time of the October 1993 proposed revisions and was further indicated by the review comments at that time.

New Section 2 – A few definitions in the old and new proposed revision are relatively generic and probably should be moved to S-526. However, at this point in the revision process, they are retained to ensure they are properly carried to S-526. These definitions are New Section 2.12 (Filtration system), New Section 2.14 (Main and Submain), New Section 2.15 (Microirrigation System), New Section 2.20 (Submain Unit),

New Section 2 -- The issue of having two types of emission uniformity in the evaluation of irrigation systems (design and field) which differ considerably in their calculations has been pointed out by several review comments. Often in our ASAE documents, the term emission uniformity is used without clarification of whether it is the design emission uniformity or the field emission uniformity. S-526 does not adequately address this issue either as its emission uniformity definition could fit either the design or field evaluation . **In the case of the proposed revisions both design emission uniformity (New Section 2.3) and field emission uniformity are defined (New Section 2.11). Wording is added to other appropriate sections to clarify this issue.**

New Sections 2.4, 2.5, 2.6, 2.9, 2.10 and 2.13 – The various terms describing a specific coefficient of variation has been a problem area for many reviewers as well as the revision committee. An attempt was made to define all of the terms and clarify confusing similar terms.

New Section 2.16, 2.17, 2.18, and 2.19 – Similarly, clarification and additions of definitions for the various statistical uniformity terms was warranted.

New Section 3.1 -- Mostly minor editorial changes. However, *interval between irrigations* was removed as it does not affect irrigation requirement. Similarly *application efficiency* was added as it does affect irrigation requirement.

New Section 3.2 – Addition of statements describing the statistical requirements and limitations.

New Section 3.2.1 – Completely new section to discuss the various coefficients of variation and their calculation.

New Table 1 -- Completely new table to augment New Section 3.2.1 and to distinguish the different named variables (V).

New Section 3.2.2 – Old Section 3.2.1.5 is added to this section for clarity and consistency. Clarifications are made that the **emission uniformities in Table 2 are field emission uniformities which differ slightly from the design emission uniformities in EP-405.**

New Section 3.2.1.1, 3.2.1.2, 3.2.3, 3.2.3.1,3.2.3.2, 3.2.3.3, 3.2.3.4, 3.2.3.4.1, 3.2.3.5 – **Significant changes are made here to regroup the various data collection activities and calculations into a common section.** Old Sections 3.2.1.1 through Old Section 3.2.3.6 are regrouped here with the exception of Old Section 3.2.1.5 which was incorporated earlier into New Section 3.2.2. The rationale for the regrouping is that several data collection activities and calculations are similar. The practicing engineer is less confused by doing slightly different but well described activities than by having to thoroughly read the procedures documented a second time in a slightly different fashion.

New Section 3.2.2.1—Equations are made generic to accommodate different calculations.

New Section 3.2.2.2 -- Grouping of two statistical uniformity terms.

New Section 3.2.3.2 -- Additions to allow both time measurements for fixed volume or volume measurements for a fixed time. This accomodation helps when evaluating extremely low flow rates.

New Section 3.2.3.2 – A major clarification is added that although completely plugged emitters should be recorded for a later calculation, they are <u>not</u> to be included in the calculation of Vqs and Vhs. The reasoning is related to the requirements of normally distributed data. This requirement has been documented in Bralts et al., (1987) but was not in the 1988 version of EP-458. The requirement to omit plugged emitters is not universally agreed upon. Camp et al., 1997, while agreeing that EP-458 intends for the omission of plugged emitters for the calculation of Vqs and Vhs, also point out that small numbers of sampling points as typically used in EP-458 can result in unrealistic system evaluations when plugged emitters exist.

New section 3.2.3.3 – A reviewer correctly suggested that the flowrate is not required to be calculated to evaluate Vqs. However it is retained as a quick check of measured flows against design flows. A statement to that effect was added.

REVISION OF EP-458: FIELD EVALUATION OF MICROIRRIGATION SYSTEMS

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Introduction

ASAE Engineering Practice EP-458 was adopted by ASAE in 1988 as the approved practice to evaluate microirrigation systems in the field. In the fall of 1992, a revision committee was assigned by SW-245, the Microirrigation Technical Committee the task to review the practice and bring any necessary revisions back to the committee for balloting. After numerous clerical and technical revisions, designed to improve the clarity of the practice, the revised practice was sent out for balloting in October 1993. SW-245 approved the revisions with 17 voting for approval and 1 dissenting vote. An attempt was made to address several minor editorial and technical points before EP-458 was sent to SW-03, the Soil and Water Standards Committee. EP-458 was disapproved by SW-03 in January, 1994 and sent back to the SW-245 revision committee with numerous editorial and several more serious technical considerations. An attempt was made to reassess the current use of EP-458 by practicing engineers, irrigators and industry. During the course of this reassessment and with further reflection on the review comments from SW-245 and SW-03, it became apparent that there are widespread differences in the perceptions of the meaning and utility of EP-458. The current revision committee is composed of the authors of this paper. It was decided at a SW-245 meeting in November 1996, that a draft revision would be presented as a paper at the ASAE annual meeting in August 1997. This would allow the opportunity to discuss the proposed changes and to get additional technical feedback on the issues being technically debated. A decision was made by the senior author of this paper to concentrate nearly all the revision efforts on improving the clarity of the document, reducing the complexity of the evaluation to the parts most often used by practicing engineers, and to implicitly state several statistical assumptions that are necessary for correct use of the EP-458. This decision leaves several technical issues unresolved, but hopefully does help reviewers get a better understanding of the Practice.

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This is contribution no. 98-35-A from the Kansas Agricultural Experiment Station. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of Kansas State University, Rutgers University or the University of Florida .

New Section 3.2.3.4.1 – Old Section 3.2.2.6 was moved closer to the calculation section rather than after Old Section 3.2.2.5 which describes a graphical technique. **Clarification is also added that the square root of the number of emitters/plant should not be decreased below 1 for the adjustment of the coefficient of variation.** This is documented by Solomon (1992) although in that case for the design emission uniformity. **Clarification is also added to indicate that Vhs should also be modified by the same process.** This is documented in Bralts et al., (1987) but was not in the 1988 version of EP-458.

New Section 3.2.3.5 – Wording added to suggest the use of the nomograph is also a quick check of the equations. Wording added to accommodate fixed time or fixed volume measurements. Wording added to explain scaling of the axes.

New Section 3.2.4 -- Wording added to indicate that the required omission of plugged emitters from the calculation of Vqs and Vhs results in the underestimation of Vpf.

New Section 3.2.4.1-- Wording added to suggest that graph can be used for quick check of calculations.

New Section 3.2.4.2 -- Wording added to have evaluator check to make sure the excessively high variation is not attributable to a high emitter manufacturer's coefficient of variation.

New Section 3.2.5 – Emitter plugging has been moved to this section from Old Section 3.4 so that all CVs can be grouped together. **Significant wording is added to indicate that the effect of emitter plugging is difficult or may be impossible to thoroughly evaluate without destructive sampling. Wording is added to indicate that calculations are at best a estimate.** Bralts et al., (1981) indicates that the equation in New Section 3.2.5.1 is appropriate for 1 of 5 possible cases of plugging. It is a simplification of a more extensive equation which handles all 5 cases. **Sample data in New Data Sheet (to be discussed later) indicate the problem of estimating the effect of plugging when sample numbers are low.**

New Section 3.2.5.2 – New section suggested in October 1993 revisions to show a Uqp.

Old Section 3.3 – This section has been completely removed with its accompanying Figure 3 and 4. Rationale is that application efficiency has too much dependence on management (ie as applied irrigation amount approaches zero, application efficiency by definition approaches 100%). This Old Section also depends on full replacement of irrigation deficit which is not necessarily appropriate for humid regions or where soils are deep and have high water holding capacity. In this day-and-age of water quality problems, ASAE probably should not make blanket statements about total replacement of irrigation deficit, even though it is appropriate for some regions and soils. If this section is returned in future revisions, it will require significant changes. Some of the present parts are incorrect and some are extremely misleading. It is easy to assume P and Pd are implicitly related when in reality it can be shown they are not. This entire section was a significant source of confusion to reviewers and also to the revision committee.

New Section 3.3 (Filtration systems) -- Few changes made. **Some reviewers have suggested this is an inadequate evaluation. Specific improvements needed are unclear**

at this time. Old Section 3.4.3.2 and accompanying Old Figure 5 were not retained because of the simplicity of the plugging equation.

Old Section 4 – This section was totally removed due to length and also because it is superseded by a New Data Sheet.

New Section 5 – Minor editorial changes.

New Section 5.4.1 – Remedies was reworded to indicate that one should lower the actual causes of the variation not simply lower the CVs.

New Data Sheet – A data sheet was constructed to outline all the procedures. Sample data was written onto the sheet so that users of EP-458 could check their calculation procedures (ie spreadsheet templates, computer programs) against the results of a known data set.

Old Figures 1 and 2 are retained as New Figures 1 and 2.

Old Tables 1 and 2 are now New Tables 2 and 3.

Unresolved Technical Issues

The omission of plugged emitters from the calculations of Vqs and Vhs results in the underestimation of the actual Vpf. This effect in quite pronounced when the sample size is small as the sample data sheet shows. Vpf was 7.7% while Vqp was 25.1%. This would appear contradictory.

Vpf incorporates the effects of plugging, emitter wear, water temperature and the emitter manufacturer's coefficient of variation. Some reviewers suggest that Vqp could be obtained as the error term in algebraic closure, since the emitter manufacturer's coefficient of variation is easy to obtain through testing of unused microirrigation materials (ASAE EP-405). Bralts et al., (1987) shows this can be done with the equation

$$Vqs = e^{-1/2} (Vqp^2 + Vk^2 + x^2\ Vhs)^{1/2}$$

where e= the number of emitters/plant, Vk is the emitter manufacturer's coefficient of variation and all other terms are presently in the proposed revisions. One problem with this method is that if water temperature or emitter wear is the actual problem it is now lumped in with plugging variation. Still that might be a manageable problem if the evaluator uses good judgement as to the real causes.

The statistical methodology in EP-458 utilizes the constant odds formulation to combine the variances. Bralts et. al., (1987) points out that two important prerequisites are that the sample data be an independent variable and that the data be from a normal (Gaussian) distribution. Compromises are required to utilize EP-458. For example, pressures along the dripline lateral are not normally distributed. They are controlled by the friction losses in the pipe and thus decrease with distance traveled. Fully plugged emitters are not normally distributed but rather exhibit a bimodal distribution (Camp et al., 1997). The importance of matching the statistical requirements has not been thoroughly evaluated in this revision. Additionally the magnitude of incorrect compromises is not understood or known by the review committee at this time.

Some evaluators prefer a evaluation technique that utilizes the design and field emission uniformity calculations. The review committee is uncertain if the proposed revisions will be acceptable to that group of evaluators and if not are there accommodations that should be made for them in the revised practice.

The adequacy of the filtration system evaluation has been questioned and it would appear this section needs strengthening.

EP-458 cites EP-405, Design and Installation of Microirrigation Systems. It is also currently being revised. It is unclear if revisions in one practice will appreciably affect the other practice at this time.

References

Bralts V. F., D. M. Edwards, and I. P. Wu. 1987. Drip irrigation design and evaluation based on the statistical uniformity concept. Advances in Irrigation, Volume 4. 67-117.

Bralts V. F., I. P. Wu, and H. M. Gitlin. 1987. Drip irrigation uniformity considering emitter plugging. Trans. ASAE 24(5):1234-1240.

Camp, C. R., E. J. Sadler, and W. J. Busscher. 1997. A comparison of uniformity measures for drip irrigation systems. Trans. ASAE 40 (in press).

Sadler, E. J., C. R. Camp, and W. J. Busscher. 1995 Emitter flow rate changes caused by excavating subsurface microirrigation tubing. In Proc. Of Fifth Int. Microirrigation Congress, 763-768. St. Joseph, MI: ASAE.

Solomon, K. H. 1992. Subsurface drip irrigation: Product selection and performance. Pages 17-39 in Subsurface drip irrigation – Theory, practices and application. CSU-Fresno, CATI Publication No. 92 1001.

APPENDIX A, REVISIONS TO ASAE EP-458

SECTION 1--PURPOSE AND SCOPE

1.1 The purpose of this Engineering Practice is to define practical engineering procedures for the field evaluation of existing microirrigation systems. Practical field evaluation procedures will encourage practicing engineers and irrigators to evaluate the adequacy of existing microirrigation systems based upon common procedures. A high degree of uniformity in application is a key factor in efficient irrigation. This Engineering Practice is aimed at a base-level evaluation; a more comprehensive evaluation may be appropriate under some circumstances.

1.2 This Engineering Practice defines field evaluation procedures for system capacity and design, water application uniformity, and filtration efficiency of microirrigation systems for comparison with recommendations in ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems.

1.3 This Engineering Practice is applicable for all types of microirrigation systems but may be impractical for the evaluation of subsurface microirrigation systems because of the labor requirement necessary for data collection.

SECTION 2--DEFINITIONS

For the purpose of this Engineering Practice only, the following terms are defined herein.

2.1 Coefficient of variation: A statistical measure of the relative dispersion of values for an independent variable as defined in this Engineering Practice. (See paragraph 3.2.1.1)

2.2 Confidence interval: An interval associated with a confidence level such that the probability that the true value of a variable falls within the described interval is equal to the confidence level.

2.3 Design emission uniformity: An estimate of the uniformity of emitter discharge rates throughout the system, as described in ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems.

2.4 Emitter discharge coefficient of variation due to hydraulics, Vqh: A statistical term used to describe the variation in emitter discharge rates in a submain unit or throughout a microirrigation system that results from hydraulic pressure differences within the system.

2.5 Emitter discharge coefficient of variation including emitter plugging, Vqp: A statistical term used to describe the variation in emitter discharge rates in a submain unit or throughout a microirrigation system, including the effects of emitter plugging.

2.6 Emitter discharge coefficient of variation, Vqs: A statistical term used to describe the variation in emitter discharge rates in a submain unit or throughout a microirrigation system for a given set of operating conditions.

2.7 Emitter discharge exponent: The emitter discharge exponent, x, as described by the equation $q = kh^x$, which characterizes the type of emitter. For example, an x value of 0.5 is common for orifice type emitters, whereas the x value for a pressure compensating emitter would be lower than 0.5.

2.8 Emitter discharge rate, qi: The instantaneous discharge rate at a given operating pressure from an individual point-source emitter or from a unit length of line-source emitter, expressed as a volume per unit of time.

2.9 Emitter manufacturer's coefficient of variation: A statistical term used to describe the variation in discharge rate for a sample of new emitters when operated at a constant temperature and at the emitter design operating pressure. See ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems, for the procedure for calculating this coefficient.

2.10 Emitter performance coefficient of variation, Vpf: A statistical term used to describe the variation in emitter discharge from the combined effects of water temperature, emitter manufacturer's coefficient of variation, emitter wear, and emitter plugging.

2.11 Field emission uniformity: An estimate of the uniformity of emitter discharge rates throughout the system, as calculated using the lower quartile method. The resulting calculation is identical to the calculation of distribution uniformity. Note that it can vary slightly from the design emission uniformity (Sec 2.3)

2.12 Filtration system: The assembly of physical components used to remove suspended solids from irrigation water. This may include both pressure and gravity-type devices and such specific units as settling basins or reservoirs, screens, media beds, and centrifugal units.

2.13 Hydraulic design coefficient of variation, Vhs: A statistical term used to describe the variation in hydraulic pressure in a submain unit or throughout a microirrigation system. Note that Vhs refers to a variation in pressure and is different than Vqh, which refers to the variation in discharge caused by variations in pressure.

2.14 Main and submain: The water delivery pipelines that supply water from the control station to the manifolds.

2.15 Microirrigation system: The physical components, operational and maintenance plans, and software systems required to apply water through microirrigation. System components that may be required include the pumping station, control and water treatment station, filtration systems, main and submain lines, manifold lines, lateral lines, emitters, valves, fittings, and other necessary items.

2.16 Statistical uniformity of the emitter discharge rate due to hydraulics, Ush: An estimate of the uniformity of emitter discharge rates in an existing microirrigation system due to hydraulics.

2.17 Statistical uniformity of the emitter discharge rate, including emitter plugging, Uqp: An estimate of the uniformity of emitter discharge rates in an existing microirrigation system, including the effects of emitter plugging.

2.18 Statistical uniformity of the emitter discharge rate, Us: An estimate of the uniformity of emitter discharge rates throughout an existing microirrigation system.

2.19 Statistical uniformity of the emitter performance, Upf: An estimate of the uniformity of emitter discharge rates throughout an existing microirrigation system as affected by the combined effects of water temperature, emitter manufacturer's coefficient of variation, emitter wear, and emitter plugging.

2.20 Submain unit: An independently controlled irrigation unit usually covering from 1 to 5 ha and including a submain manifold, lateral lines, and emitters.

2.21 Water application uniformity: The uniformity of emitter discharge rates as defined by the field emission uniformity or the statistical uniformity defined in this Engineering Practice.

SECTION 3–EVALUATION PRINCIPLES AND PROCEDURES

3.1 System capacity and design. The capacity of a microirrigation system must be adequate to satisfy the irrigation water requirement for the specific land area to be irrigated.. The irrigation water requirement is governed primarily by the crop evapotranspiration rate, application efficiency, and water application uniformity. The system design must be adequate to satisfy the operational pressure, water application uniformity, filtration, and chemical injection requirements of the microirrigation system as described in ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems.

3.2 Water application uniformity. The water application uniformity is affected by the hydraulic design, topography, operating pressure, pipe size, emitter spacing, and emitter discharge variability. The emitter discharge variability is due to water temperature variation, emitter manufacturer's variation, emitter wear, and emitter plugging. The coefficient of variation and the statistical uniformity shall be used to evaluate the emitter discharge variation and to differentiate between hydraulic design and emitter performance variation. The data used in developing the statistical measures are assumed to be independent and normally distributed. These requirements are not always satisfied, particularly in the case of emitter plugging, which exhibits a bimodal distribution. However, this engineering practice can still be useful in estimating the water application uniformity and in attempting to differentiate among the various factors affecting system performance.

3.2.1 Coefficient of variation

The coefficient of variation can be used as a measure of the various factors affecting the system performance. Some of these various coefficients of variation (Table 1) are calculated directly, another term is calculated using the constant odds uncertainty principle from statistics, and the remaining term is estimated by simplifying assumptions related to emitter plugging.

TABLE 1. COEFFICIENTS OF VARIATION FOR EVALUATING MICROIRRIGATION SYSTEMS

Term	Abbreviation	Calculation Method
Emitter discharge coefficient of variation	Vqs	Direct
Hydraulic design coefficient of variation	Vhs	Direct
Emitter discharge coefficient of variation due to hydraulic design	Vqh	Direct
Emitter performance coefficient of variation	Vpf	Constant Odds Formulation
Emitter discharge coefficient of variation including emitter plugging	Vqp	Estimation

3.2.2 Statistical uniformity. The statistical uniformity shall be used to evaluate water application uniformity within a submain unit or throughout a microirrigation system. The statistical uniformity was selected instead of the emission uniformity for this Engineering Practice because of its ability to differentiate among the various factors affecting emitter discharge variation. In order to facilitate comparisons with ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems, a table of equivalent uniformities has been developed. Table 2 relates the statistical uniformity, U_s, to the field emission uniformity, EU, as estimated using the lower quartile method of calculating distribution uniformity. Note that EU as calculated with this method will vary slightly from the design emission uniformity as expressed in the equations in EP-405.

TABLE 2--COMPARISON OF UNIFORMITIES, %

Method acceptability	Statistical uniformity, Us	Emission[1] uniformity, EU
Excellent	100-95	100-94
Good	90-85	87-81
Fair	80-75	75-68
Poor	70-65	62-56
Unacceptable	<60	<50

[1] Identical to distribution uniformity calculation.

3.2.2.1 The three statistical parameters (mean, standard deviation, and coefficient of variation) for emitter discharge and the hydraulic pressure are determine as follows:

$$\bar{a} = \frac{1}{n} \sum_{i=1}^{n} a_i$$

$$S_a = \left(\frac{1}{n-1} \left[\sum_{i=1}^{n} a_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} a_i \right)^2 \right] \right)^{1/2}$$

$$V_{as} = \frac{S_a}{\bar{a}}$$

where

a = emitter discharge rate, q, when determining the parameters related to discharge rate (q, Sq, Vqs)

or

a = hydraulic pressure, h, when determining the parameters related to pressure (h, Sh, Vhs
n = the number of randomly selected emitters
i = a subscript identifying individual emitters

3.2.2.2 The statistical uniformity of the emitter discharge rate, Us, and the statistical uniformity of the emitter discharge rate due to hydraulic design, Ush, are determined as follows:

Us = 100 (1 - Vqs)
Ush = 100 (1 - Vqh)

where

Vqh = x Vhs
where x = emitter discharge exponent (obtained from the manufacturer or through testing).

3.2.3 Coefficients of variation Vqs and Vhs. The emitter discharge coefficient of variation, Vqs, and the hydraulic design coefficient of variation, Vhs, are determined using the following procedure:

3.2.3.1 Decide upon a reasonable sample size, n, for the 95% confidence interval desired for a given Vqs or Vqh from Table 3.

TABLE 3--95% CONFIDENCE INTERVAL, ±%

		Number of observations, n			
Us or Ush	Vqs or Vqh	18	36	72	144
95	0.05	1.8	1.2	0.8	0.6
90	0.10	3.5	2.4	1.7	1.2
85	0.15	5.4	3.7	2.5	1.8
80	0.20	7.3	5.0	3.4	2.4
75	0.25	9.3	6.3	4.4	3.1
70	0.30	11.4	7.8	5.4	3.8
65	0.35	13.7	9.3	6.5	4.6
60	0.40	16.1	11.0	7.6	5.4

3.2.3.2 Individually measure the time required to fill a constant volume container (i.e., 200 mL)- or the volume of water discharged by n randomly selected emitters during a fixed time period (i.e., 15 minutes). Also measure the emitter pressure for n randomly selected emitters. Record the fraction of completely plugged emitters, C. Do not include any completely plugged emitters in the calculation of Vqs and Vhs. The effect of emitter plugging on statistical uniformity will be handled as a separate issue later in this document. Theoretically the flows and pressures should be from independant sampling of the emitters, but it has been found acceptable to use the same emitters for both measurements.

3.2.3.3 Calculate the emitter discharge rates for each emitter using any convenient unit of flow rate. The calculation of flow rate is not absolutely necessary but provides a quick check of the data against the design flow rates.

3.2.3.4 Calculate the coefficients of variation, Vqs, Vhs, and Vqh, and the uniformities, Us and Ush using the equations in paragraphs 3.2.2.1 and 3.2.2.2

3.2.3.4.1 The number of emitters per plant may affect Vqs and Vhs because of the overlapping nature of the variance. For this situation, Vqs and Vhs shall be adjusted by dividing each term by the square root of the number of emitters per plant or by 1, whichever is greater.

3.2.3.5 A simplified graphical technique that uses approximately one-third of the data collected also can be used for a quick field evaluation and to check the calculations from the equations. Vqs and Us can be determined from Figure 1 by comparison of the sums of the highest one-sixth and the lowest one-sixth discharge volumes or collection times. Similarly, Vhs can be determined from Figure 1 by comparison of the the highest one-sixth and the lowest one-sixth emitter pressures. Vqh and Ush then are determined from equations in 3.2.2.2. The use of Figure 1 can be facilitated by multiplying or dividing the terms on both axes by a common factor. In the case of plugged emitters (i.e., C>0), the equations referred to in 3.2.2.1 and 3.2.2.2 must be used.

3.2.4 Emitter performance variation. Emitter performance variation can be used to estimate the emitter discharge variability due to water temperature, emitter manufacturer's coefficient of variation, emitter wear and emitter plugging. Note that the required omission of completely plugged emitters from calculation of Vqs and Vhs results in underestimation of Vpf. The emitter performance coefficient of variation, Vpf, shall be determined using the constant odds uncertainty principle as follows.

$$Vpf_f = (Vqs^2 - Vqh^2)^{1/2}$$

where

Vqs = emitter discharge coefficient of variation

Vqh = emitter discharge coefficient of variation due to hydraulics

The statistical uniformity of the emitter performance, Upf is determined as follows:

$$Upf = 100\,(1 - Vpf)$$

The resulting emitter performance coefficient of variation can be expressed as a decimal or as a percentage (i.e., 0.1 or 10%)

3.2.4.2 A simple graphical technique for determining the emitter performance coefficient of variation is shown in Fig. 2. This also can be used to check the calculations in the equations.

3.2.4.3 If the emitter performance coefficient of variation is excessively high (greater than 0.2 or 20%) and can not be attributed to a high emitter manufacturer's coefficient of variation, it is recommended that additional emitter flow and pressure data be collected. If the subsequent emitter performance coefficient of variation is still excessively high, emitter cleaning and/or replacement should precede further evaluation.

3.2.5 Emitter plugging. Field evaluation of emitter plugging is a difficult task. Determining if an emitter discharge rate is altered by partially plugging or by manufacturing variation may be impossible without a destructive evaluation. One simple method of assessing the approximate effects of emitter plugging on the statistical uniformity can be made by modifying the emitter flow variation assuming that only complete plugging is present in the microirrigation system. This method should be regarded only as an approximation, because in reality combinations of complete and partial plugging probably exist in the microirrigation system. The possible sources of emitter plugging are physical, chemical, and biological in nature.

3.2.5.1 Calculate the emitter discharge coefficient of variation including emitter plugging, Vqp, using the following equation:

$$V_{qp} = \left[\frac{1}{1-C} (V_{qs}^{2} + 1) - 1 \right]^{1/2}$$

where

Vqs = the emitter discharge coefficient of variation

(1-C) = the proportion (decimal) of emitters openly flowing

3.2.5.2 Calculate the statistical uniformity of the emitter discharge rate including emitter plugging, Uqp, by the equation

Uqp = 100 (1 - Vqp)

where

Vqp = the emitter discharge coefficient of variation including emitter plugging.

3.3 Filtration systems. The field evaluation of microirrigation systems should include a determination of removal efficiency and pressure differential across the filtration system. The effectiveness of the filtration system can be assessed indirectly by evaluating the degree of emitter plugging.

3.3.1 Removal efficiency. The removal efficiency, Er, of a filtration system shall be determined by the following equation:

$$E_r = 100 \left(1 - \frac{S_{out}}{S_{in}} \right)$$

where

S_{out} = the concentration of suspended solids, mg/L, in filter outlet

S_{in} = the concentration of suspended solids, mg/L, in filter inlet

3.3.1.1 The equation in paragraph 3.4.1 also can be used to determine Er for an individual constituent of the total suspended solids.

3.3.1.2 Water samples shall be taken immediately upstream and downstream of the filtration system, 30 minutes after start-up or 30 minutes after the most recent backflush cycle to determine removal efficiency, Er.

3.4.1.3 The time of the season that the water samples are taken may affect the outcome of this evaluation. For this reason, the time of year should be recorded, as well as any special considerations related to water quality.

3.4.2 Pressure differential. The differential pressure (inlet pressure minus outlet pressure) before and after filter backflushing takes place shall be recorded. If the differential pressure after backflushing significantly exceeds the filter manufacturer's specifications, the source of this excess differential needs to determined and corrected. Excess pressure differential may be caused by insufficient flushing flow rates or time, plugged media underdrains, screens partially plugged by particles that need to be removed manually, or other problems. Conversely, if the differential pressure is constantly very low, then the filter should be checked for defective screens, worn seals, or inoperable flush valves.

SECTION 4--REPORTING RESULTS

4.1 Irrigation system description. The following information shall be reported.

4.1.1 Evaluation date, irrigation system location, total irrigated area, farm address, and irrigated parcel location.

4.1.2 Crops irrigated, variety, spacing, age, and rooting depth.

4.1.3 Soil type, description, water holding capacity, and infiltration rate.

4.1.4 Topography, major land slopes, and elevation differences between the water source, and pumping station.

4.1.5 Water supply, water source, pumping station, system capacity, and available pressure.

4.1.6 Control station, water measurement, filtration, treatment, addition of amendments, and pressure control.

4.1.7 Mainline material, size, length, installation depth, and differential elevation to submain units under investigation.

4.1.8 Submain manifold material, size, pressure control, length, lateral spacing, installation depth, and major slope.

4.1.9 Lateral line material, size, length, emitter spacing, installation depth, and major slope.

4.1.10 Emitter type, manufacturer, size, and installation depth.

4.2 Evaluation data collection. The following information shall be collected and reported.

4.2.1 Water supply, mainline flow rate, and pressure at the water source.

4.2.2 Irrigation practice, allowable deficit, irrigation frequency, and duration.

4.2.3 Submain manifold flow rate, and pressure at the head of the manifold.

4.2.4 Emitter discharge time or volume, rate, and pressure for n random locations in the microirrigation system or submain unit.

4.2.5 Water temperature at the emitter testing location.

4.2.6 Filtration efficiency, inlet water sample, outlet water sample, differential pressure across the filter, and rate of percentage of emitter plugging.

4.3 Evaluation analysis results. The following results shall be reported.

4.3.1 System capacity and design. A statement regarding the adequacy of the existing system design and its conformance with ASAE Engineering Practice EP405, Design and Installation of Microirrigation Systems, shall be made based upon the irrigation system description data.

4.3.2 Water application uniformity. Based upon the emitter discharge and pressure data collected, the submain unit or microirrigation systems statistical uniformity, Us, hydraulic variation, Vqh, and emitter performance variation, Vpf, shall be reported. In addition, a statement regarding the adequacy of the various system components based upon the interpretation guidelines found in paragraph 5.4 shall be reported.

4.3.3 Filter system performance. Based upon the data collected regarding the irrigation system filter, a statement regarding the removal efficiency, Er, and pressure differential shall be reported.

4.4 Evaluation interpretation guidelines. The following guidelines shall be used to report the adequacy of the irrigation system based on the evaluation results.

4.4.1 Statistical uniformity. The criteria for an acceptable statistical uniformity shall be as shown in Table 2. A statistical uniformity of 80% or greater shall be required before fertilizer injection through the microirrigation system is recommended, unless otherwise indicated by experience or practice. Possible ways to improve the statistical uniformity include increasing the number of emitters per plant, improving the hydraulic design and/or replacement of worn, degraded or plugged emitters.

4.4.2 Hydraulic variation. The criteria for an acceptable hydraulic design coefficient of variation, Vhs, are: 10% or less, excellent; 10-20%, very good; 20-30%, fair; 30-40%, poor, and greater than 40%, unacceptable. Possible ways to improve the hydraulic variation include readjustment of pressure regulation devices, repair or removal of pinched lateral lines and the redesign of the hydraulic system.

4.4.3 Emitter performance variation. The criteria for emitter performance variation, Vpf, are: 5% or less, excellent; 5-10%, very good; 10-15%, fair; 15-20%, poor; and greater than 20%, unacceptable. Possible ways to improve emitter performance include cleaning plugged emitters, replacing poorly performing emitters and using microirrigation laterals with lower emitter manufacturer's coefficient of variation.

Cited Standard:

ASAE EP405, Design and Installation of Microirrigation Systems

ASAE EP-458 Data and Calculation Form

Date	7/29/97

Irrigation system description (Section 5.1)

Record above necessary information on as many additional sheets as may be required.

System measurements on evaluation date (Section 5.2)

Irrigation practices (allowable deficit, frequency and duration) Allowable deficit, < 20 mm in root zone. Frequency, as needed, but restricted to twice daily. Duration, as required by deficit.

Microirrigation system flowrate and pressure	20 l/s	240 kPa	
Submain flow rate and pressure at head of manifold	5 l/s	78 kPa	
Water temperature measured at the emission point	18 C		
Design emitter flowrate as specified by the manufacturer	1.86 l/hr-m	Use similar units for Qi calculation	
Design emitter pressure as specified by the manufacturer	69	Use similar units for Hi measurement	

Emitter exponent as specified by the manufacturer or obtained by testing *(See Section 3.2.2.2)*, **x** =			0.50
No. of emitters/plant *(See Section 3.2.3.4.1)*	2	Reasonable no. of samples *(Section 3.2.2.1)*	18

NOTE: Expand table shown below as required for number of samples

Sample No	Volume or Time	Resultant Qi	Hi
1	716 ml/15 min	2.148	75
2	580	1.740	74
3	684	2.052	65
4	645	1.935	63
5	611	1.833	75
6	565	1.695	66
7	674	2.022	56
8	539	1.617	74
9	611	1.833	69
10	664	1.992	72
11	539	1.617	74
12	595	1.785	62
13	515	1.545	58
14	674	2.022	74
15	565	1.695	68
16	509	1.527	77
17	705	2.115	69
18	751	2.253	66
Mean		1.857	68.722
Standard Deviation		0.219	6.201
Coefficient of Variation		0.118	0.090
Check of Qi & Hi to design		Very close to design	

Uniformity Terms and EP-458 Section		
Vqs =	0.118	*Sec. 3.2.2.1*
Vhs =	0.090	*Sec. 3.2.2.1*
Vqh = xVhs =	0.045	*Sec. 3.2.2.2*
Us =	88	*Sec. 3.2.2.2*
Ush =	95	*Sec. 3.2.2.2*

Adjustments for multiple emitters/plant		
Vqs =	0.118/SQRT(2)=0.083	*Sec. 3.2.3.4.1*
Vhs =	0.090/SQRT(2)=0.064	*Sec. 3.2.3.4.1*
Vqh = xVhs =	0.064 x 0.50 =0.032	*Sec. 3.2.3.4.1*
Us =	92 +/- 4%	*Sec. 3.2.3.4.1*
Ush =	97 +/- 2%	*Sec. 3.2.3.4.1*

Vpf =	0.077	*Sec. 3.2.4*
Upf =	92 +/- 4%	*Sec. 3.2.4*

Vqp =	0.251	*Sec. 3.2.5.2*
Uqp =	75 +/- 10%	*Sec. 3.2.5.2*

No. of completely plugged emitters observed during evaluation	1 emitter was found and skipped.
Fraction of completely plugged emitters observed during evaluation, **C**	C = 1/(18+1) = 0.053

Assessment of filtration system (Section 3.3)			
Sint, mg/l =	20	**Pin, kPa =**	78
Sout, mg/l =	15	**Pout, kPa =**	77
Er =	25	**Pdiff, kPa=**	1

Evaluated by Mike Roman

Comments Checking equations with nomographs is not applicable due to plugging. Since sample size is small, Upf and Uqp are contradictory. More sampling is suggested.

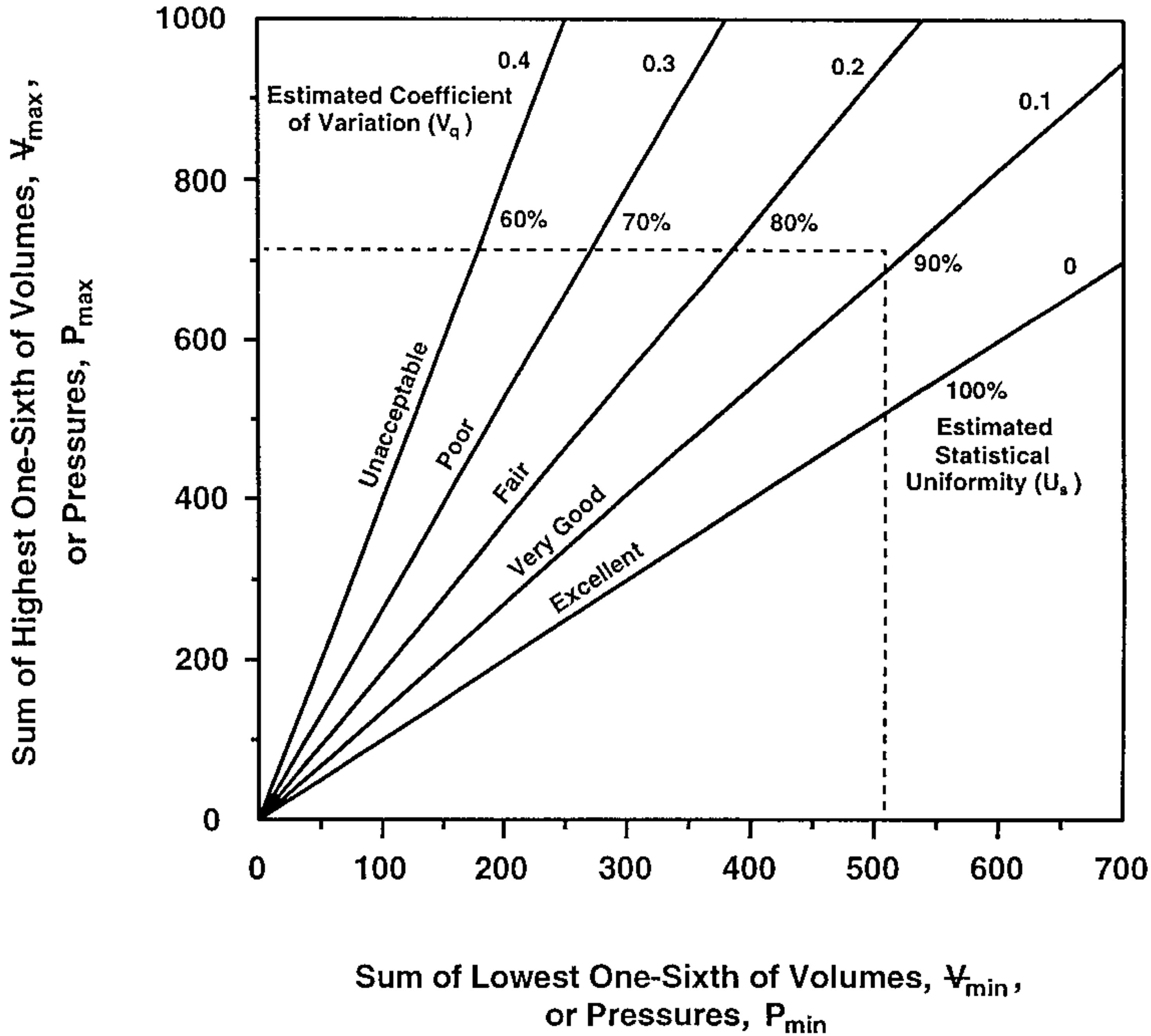

FIGURE 1. STATISTICAL UNIFORMITY NOMOGRAPH.

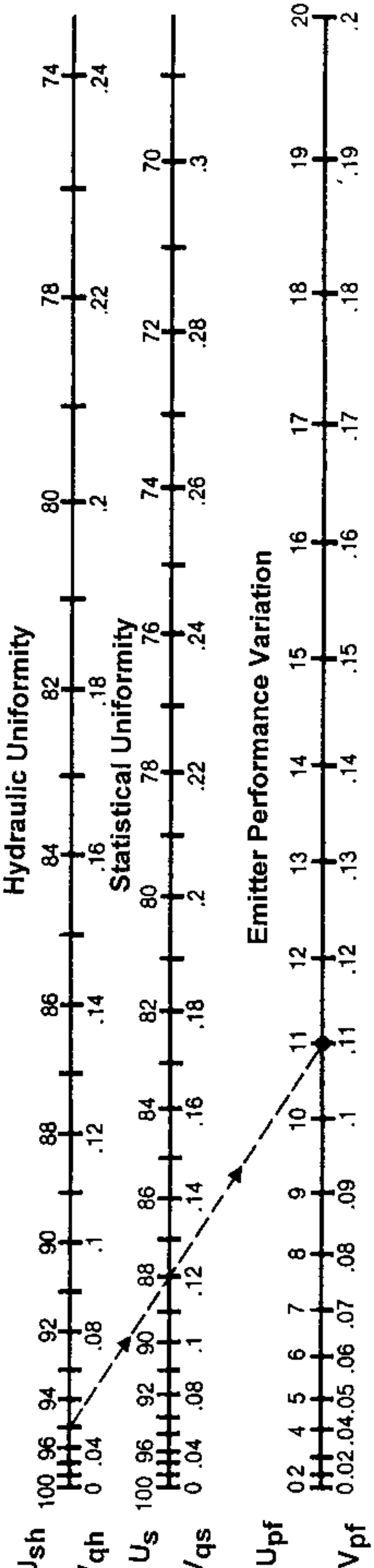

FIGURE 2. EMITTER PERFORMANCE NOMOGRAPH