REDUCING ENERGY REQUIREMENTS FOR SPRINKLER SYSTEMS

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Introduction

According to the 1980 Irrigation Journal Survey, sprinkler irrigation is practiced on approximately 4.1 million acres in Washington, Idaho and Oregon. Of that total, approximately 75 percent is irrigated by hand move, side roll and solid set systems. Much of this land is on rolling hills with fairly shallow soils and is unsuitable for surface irrigation. The soils are mostly medium- to low-intake rate soils which are less than optimum for center pivot application. For these reasons, farmers in the Pacific Northwest will continue using stationary lateral systems despite rising energy costs. Power rates in Idaho are expected to increase approximately 15 percent per year.

High levels of application uniformity are easily obtainable with center pivot systems. However, stationary system uniformities are generally lower and may be reduced to unacceptable levels as farmers attempt to reduce power costs by lowering system pressure. The objective of this study was to determine whether pressure could be reduced on existing systems without making major changes in sprinkler spacing.

Two types of outdoor grid tests were conducted to measure uniformity. The first type was standard single sprinkler patterns (SSP) as described in ASAE S-330. The second type was lateral sprinkler patterns as described by Hart and Heermann (1976). The lateral tests will be described first.

Lateral Pattern Tests

A side roll lateral with 5.3-foot wheels and 40-foot sprinkler spacing was used for the lateral tests. Two laterals were oriented perpendicular to each other to obtain simultaneous tests with two different wind directions. Each lateral was divided into a high pressure section and a low pressure section. Six-inch diameter cans were used as collectors and grid spacing was 10 feet. A total of 11 tests were run with 4 lateral patterns for each test. Wind speeds were between 3 and 8 miles per hour and averaged 5 miles per hour for these tests.

The high pressure tests used a standard straight bore 9/64-inch nozzle operating at 55 psi, while the low pressure tests used a straight bore 5/32-inch nozzle at 30 psi, producing approximately the same discharge. The lateral pattern tests were arranged in a random sequency and overlapped to simulate side roll system operation with 40-, 50-, and 60-foot lateral move distances. Uniformities were calculated over a complete simulated irrigation comprising 12 lateral positions with a different wind speed in each position. There appeared to be no significant effect due to wind direction, so uniformities were averaged for the two perpendicular laterals. A sequence of three irrigations was simulated and the cumulative uniformities were calculated for one, two and three irrigations. Figure 1 shows the results. The dashed lines represent the normal system operation where the laterals are placed at the same positions each irrigation (no offset). The solid lines resulted from an offset procedure where the lateral was offset one wheel revolution from the normal position for the second and third irrigations (2nd only for 40-foot moves). Intuitively this offsetting procedure should result in higher cumulative uniformities. However, these results showed little effect due to offsetting except when the low pressure nozzles were used with 60-foot moves.

The low pressure tests yielded uniformities nearly equal to the high pressure tests for 40- and 50-foot moves but did not perform well for the 60-foot moves for an individual irrigation.

Single Sprinkler Patterns

A series of single sprinkler pattern tests was conducted to compare the results of uniformity simulations with the lateral pattern test results. Also, it was desired to obtain tests over a wider range of wind speeds and determine the effect of wind speed on uniformity. Paired tests were conducted with two adjacent, non-overlapped sprinklers operated simultaneously. The majority of the tests were run using the 9/64-inch straight bore nozzle at 55 psi in one sprinkler and a 5/32- or 11/64-inch square nozzle (Rainbird CD3) at 30 psi in the adjacent sprinkler (all sprinklers were model 30 Rainbird).* Additional paired tests were run comparing the square nozzles at 25 and 35 psi and comparing the square nozzles with flow control (Nelson FCN) nozzles.* The collectors were 6-inch diameter cans and the collector spacing was 7.5 feet in most of the tests. The tests were run from one to three hours, depending on wind speed variability.

Lateral System Simulations Using Single Sprinkler Patterns

A computer simulation model was developed to utilize single sprinkler patterns and simulate any type of lateral or solid set system, including the effect of wind speed and direction. For a given sprinkler nozzle size and pressure,

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*Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U.S. Department of Agriculture.

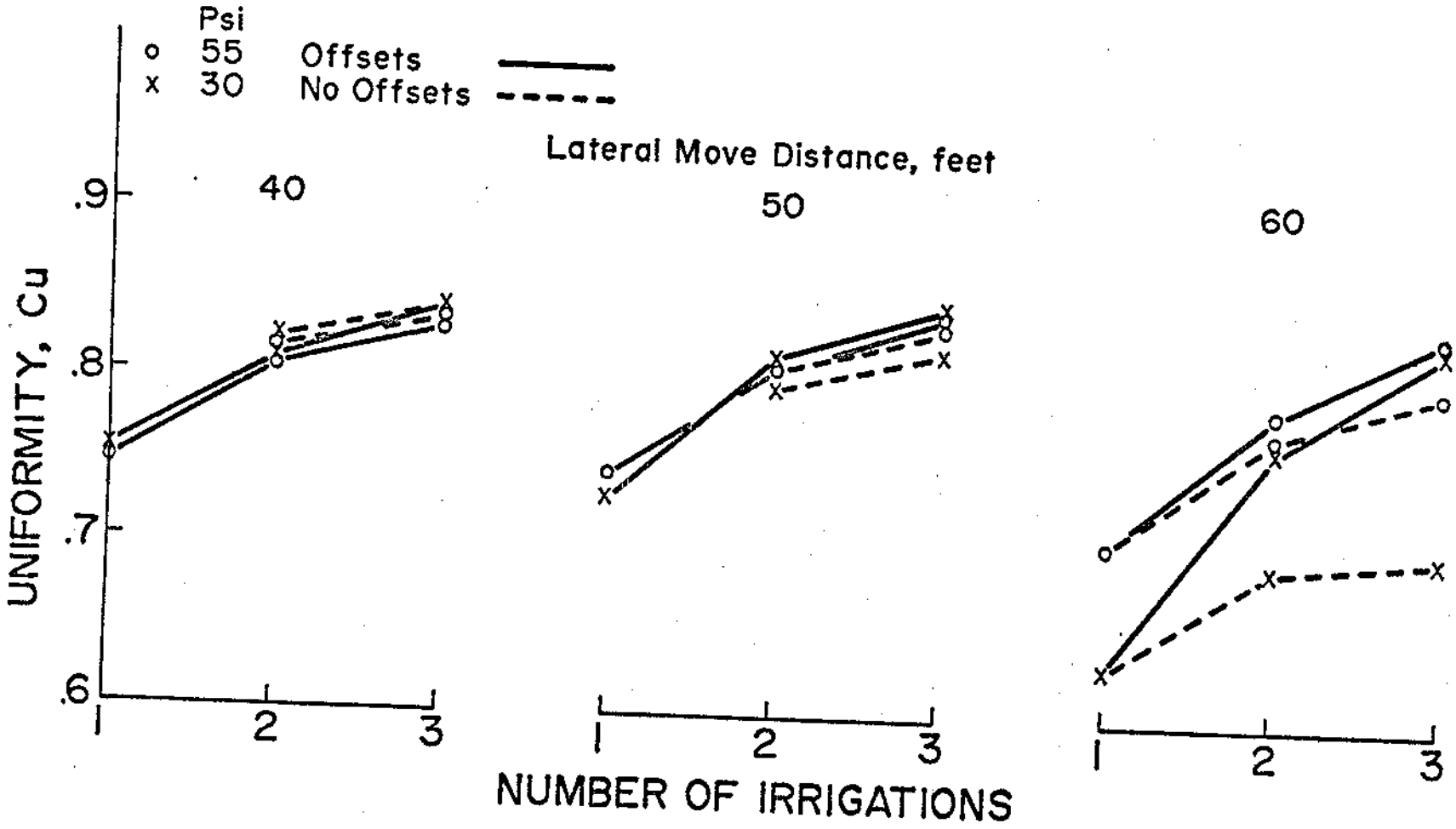

FIG. 1. SIDEROLL WHEELINE SPRINKLER LATERAL TESTS

a group of patterns is selected at different wind speeds. The model rotates the patterns to obtain the desired wind direction and interpolates between patterns to obtain the desired wind speed. Sprinkler patterns are superimposed upon a field grid and field uniformity is calculated on a desired subarea.

Figure 2 shows cross sections of a simulated lateral pattern comparing the application rates from the high and low pressure sprinklers described above. Reducing pressure while maintaining constant discharge results in a reduced pattern width and increased peak application rate. This increased peak rate could produce runoff on some medium-low intake rate soils and is a factor to consider in low pressure conversions. Also, increasing wind speed tends to compress the pattern width as well as to shift the pattern laterally.

Simulations were run for wind speeds from 4 to 12 miles per hour, lateral moves of 40, 50 and 60 feet using the high and low pressure nozzles. The uniformity results are shown in Figure 3. Uniformities were calculated for wind direction both parallel and perpendicular to the lateral. Wind direction had a small effect on uniformity and the results shown in Figure 3 are averages of two directions. Figure 3 shows a gradual decrease in uniformity with increased wind speed up to about 10 miles per hour, where uniformity seems to level off. This leveling off effect needs to be confirmed by further tests before it could be considered definite.

The low pressure nozzles maintained about the same uniformity as the high pressure nozzles for lateral moves of 40 and 50 feet. This agrees with the lateral pattern test results. The average uniformities from Figure 3 are somewhat higher, however, than for the lateral pattern tests at equivalent wind speeds. Comparing the 50-foot move distance at 5 miles per hour, the single pattern simulations gave a uniformity of 0.84, while the lateral tests gave 0.74. This tendency is due to the fact that the lateral tests were overlapped with random wind speeds and directions, while the single pattern tests were overlapped with a constant wind speed and direction. Thus, the lateral tests would be more indicative of the overall field uniformity with variable winds.

Effect of Pressure Level on Uniformity

The tests discussed thus far were limited in pressure range. Additional tests were obtained from a thesis by Aliaga (1981) who tested several types of sprinklers and nozzles at pressures between 15 and 30 psi. Tests were selected for the 5/32 and 11/64 square orifice nozzles and uniformity simulations were run. Figure 4 shows the results combined with the previous tests for 40- and 50-foot moves. Uniformity generally increases with pressure and the results are scattered due to wind variability. The range of scatter at a given pressure level is similar to the variation due to wind in Figure 3. Another series of tests from Aliaga (1981), using a 3/16 round bore nozzle at pressures from 10 to 55 psi, gave the results shown in Figure 5. Curves were fitted to the data for 40-, 50-, and 60-foot move distances. As expected, the round bore nozzle gave lower uniformities at the lower pressures (15-30 psi), and the two types of nozzles approached similar uniformities at higher pressures.

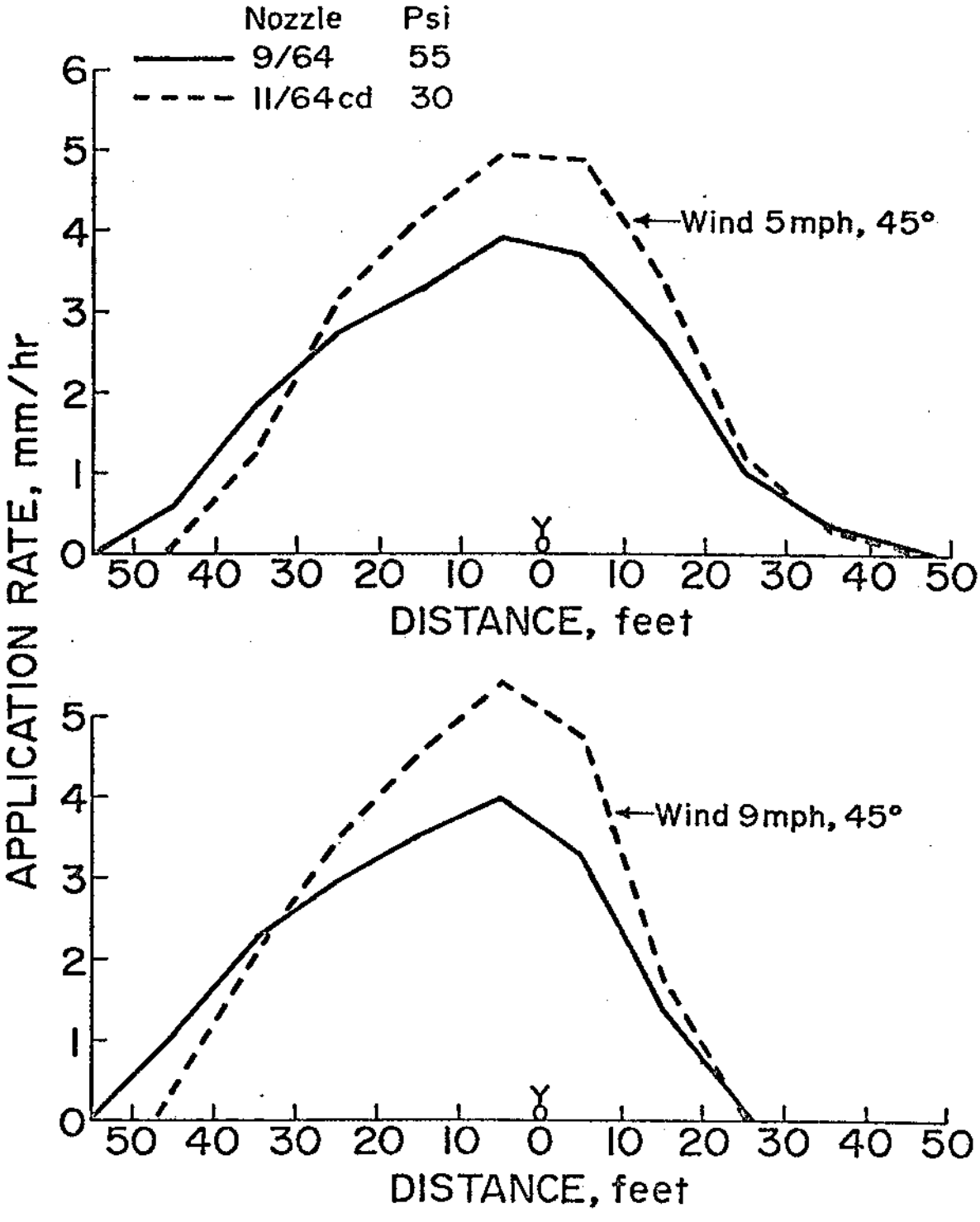

Figure 2. Lateral application rates for high and low pressure.

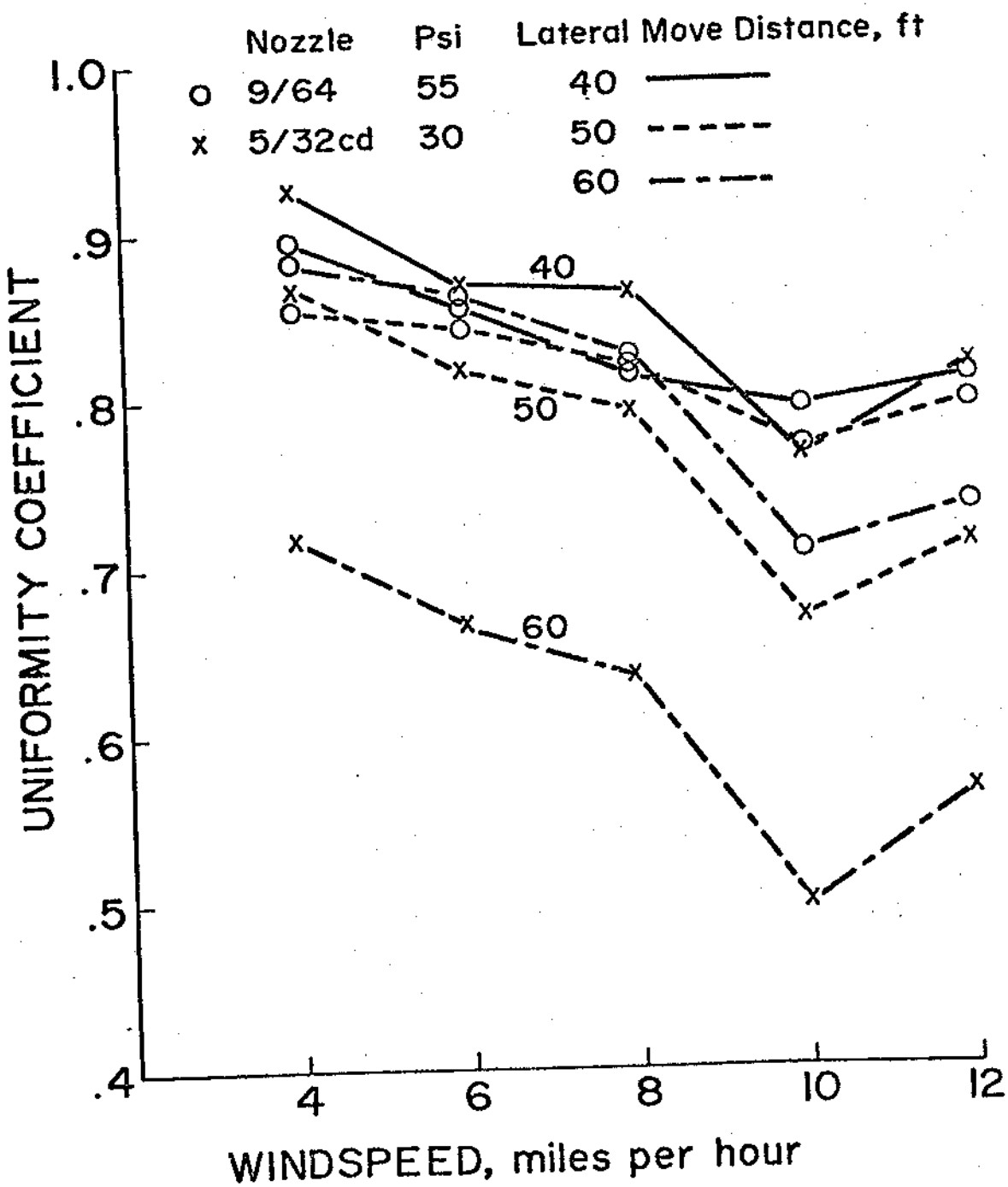

Figure 3. Effect of windspeed on uniformity.

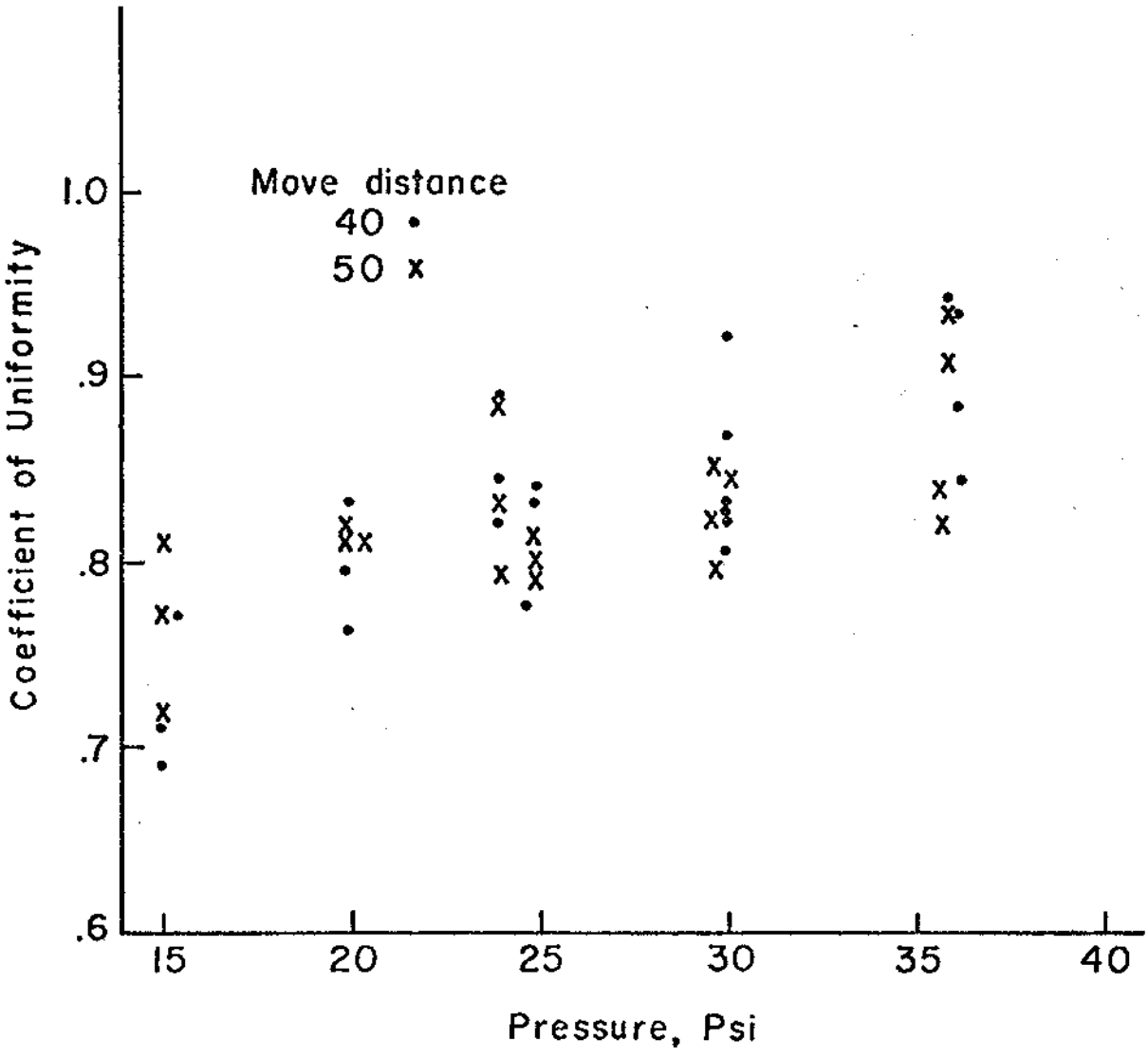

Figure 4. Effect of pressure on uniformity for square nozzles (5/32 and 11/64 CD)

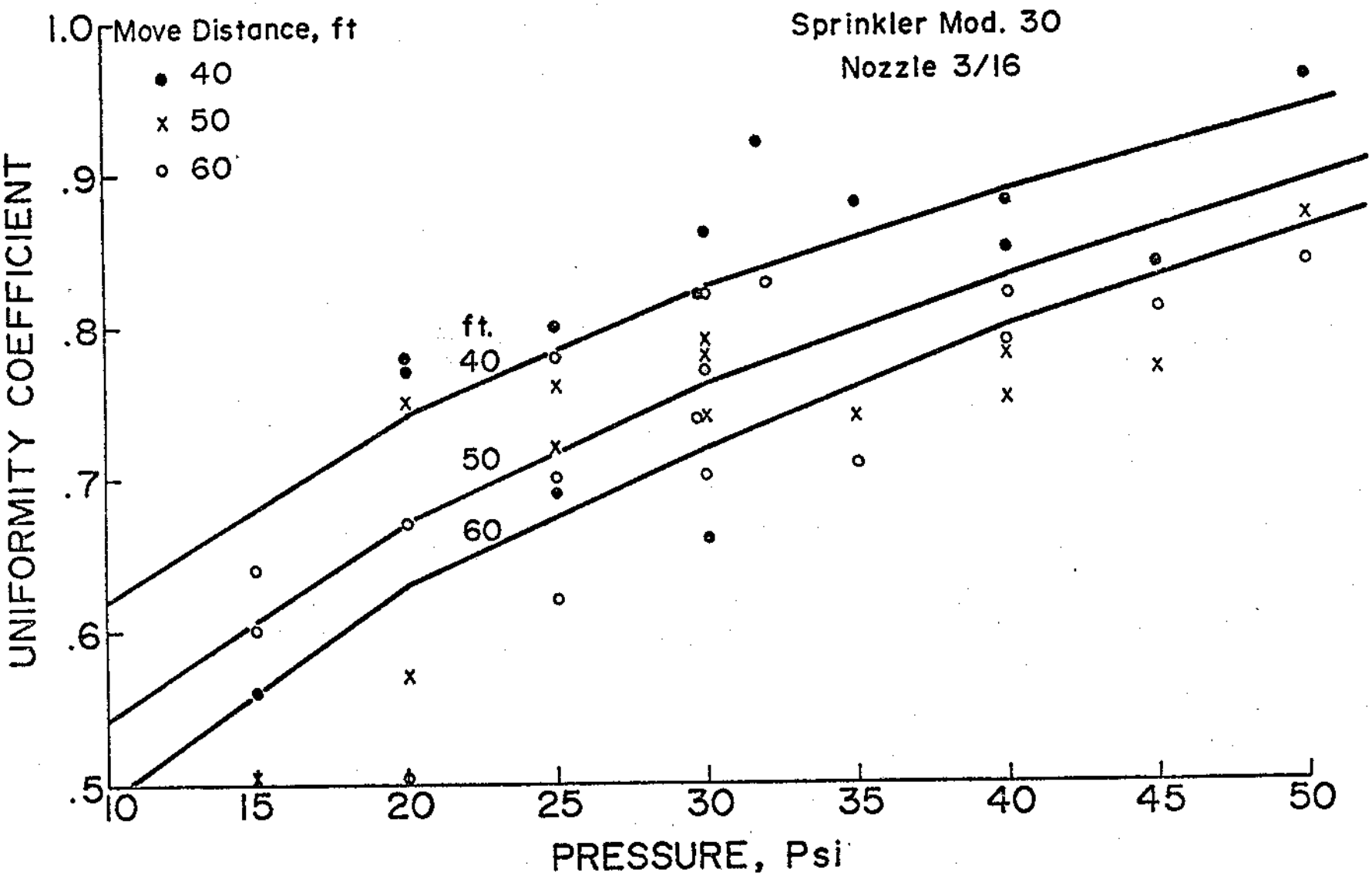

Figure 5. Effect of pressure level and lateral move distance on uniformity.

Several tests were conducted with flow control nozzles (Nelson FCN 4.3 and 5.0 gpm) at pressures between 30 and 35 psi. Uniformities between 0.8 and 0.85 were attained using these tests at 40- and 50-foot spacings and wind speed of 5-7 miles per hour.

Summary and Conclusions

Uniformity of application is an important factor in stationary sprinkler systems, particularly when reduced operation is considered. Paired outdoor sprinkler tests were conducted to compare relative uniformities obtainable at two pressure levels, 55 psi and 30 psi, and sprinkler discharge of about 4 gallons per minute. Both single sprinkler pattern tests and lateral pattern tests were conducted at wind speeds from 2 to 12 miles per hour.

Lateral tests were overlapped in a random sequence to simulate a full 12-set irrigation. The single sprinkler patterns were overlapped to simulate lateral operation with constant wind speed. This resulted in higher uniformities than the overlapped lateral tests with variable wind speeds. Uniformities decreased with wind speeds up to about 10 miles per hour.

Both types of tests indicated that for 40- and 50-foot lateral move disances, the low pressure tests gave uniformities nearly equivalent to the higher pressure. For 60-foot moves, the low pressure significantly reduced uniformity. The effect of a lateral offset procedure on the cumulative uniformity for up to three irrigations was also studied. The offsets had a slight benefit for 50-foot moves and a large benefit for 60-foot moves with the lower pressure.

The effect of various pressure levels on uniformity was studied for standard nozzles and for square nozzles. At higher pressures, both types gave good uniformity, and at lower pressures the square nozzles gave better uniformities. Both square nozzles and flow control nozzles gave acceptable uniformities at pressures between 30 and 35 psi with 40- and 50-foot moves.

References

1. Irrigation Journal, 30(6). 1980.

2. Hart, William E. and Dale F. Heermann. 1976. Evaluating water distributions of sprinkler irrigation systems. Colorado State Univ. Exp. Sta. Tech. Bull. 128.

3. Procedure for Sprinkler Distribution Testing for Research Purposes. ASAE S-330. 1981 Yearbook.

4. Aliaga Uria, Carlos. 1981. A design procedure for low head side-roll sprinkler systems. M.S. Thesis, University of Wyoming, Agricultural Engineering Dept.