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A PORTABLE BOOM-MOUNTED RAINFALL SIMULATOR

by

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SUMMARY: A rainfall simulator was built based on an existing design but with improved portability, air injection, water storage and different nozzle arrays for various research needs. Time needed to set up or to move between plots is less than five minutes.

KEYWORDS: Simulation, Rainfall, Nozzles, Water, Air

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A Portable Boom-Mounted Rainfall Simulator

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Abstract

A rainfall simulator was constructed based on an existing design but with improved portability, air injection, water storage and ease in changing nozzle arrays for different research uses. It consists of a flat bed trailer with water tanks for on board water storage and a rotating turret and boom attached at the rear of the trailer. The boom is rotated to one side of the trailer for applying water to plots and positioned over the trailer and tanks for road transport. Hydraulic cylinders are used to control the boom. Interchangeable spider-like frames that hold the nozzles are suspended from the end of the boom. The simulator can apply water at up to 100 mm/hr (4 in/hr) for at least 90 minutes before refilling is needed. Typical time for set up is five minutes and movement between adjacent plots is three minutes.

Introduction

Rainfall simulators (RS) have been used extensively to conduct infiltration, surface water runoff and soil erosion research during the last few decades. Different types of RS have been developed which differ by method of water application, portability and size of area that water is applied to, among other reasons (Bubenzer, 1979). Water has been applied with various types of nozzles that can be held stationary or mounted on moving booms.

Shelton et al (1985) developed a unique continuous-application variable-rate RS with nozzles arranged in a square array. Application rate was varied by using air injection which displaces some of the water flow just above each nozzle. However, the most significant aspect of air injection is that drop sizes decrease as application rate is decreased, which is also characteristic of natural rainfall. When air is injected, application rate is decreased and nozzle pressure is increased which reduces drop size. With water only, increasing pressure increases application rates and decreases drop sizes, of which the latter two vary opposite to natural rainfall. Air injection is also more convenient for changing application rate than some of the water diverting techniques such as rotating slotted disks, or by changing nozzles or turning them on and off.

Akron USDA-ARS Rainfall Simulator

A portable boom-mounted, continuous-application RS was constructed using the basic design developed by Shelton et al (1985). Major differences include improved portability and transport, water storage, modified air injection, and interchangeable nozzle frames. A 5.5 m (18 ft) flat bed trailer was the foundation on which a rotating turret and 4.6 m (15 ft) boom was added which can hold various spider-like pipe frames on which the spray nozzle assemblies are mounted. The RS is shown in operating position in figure 1. For transport position between field sites, the boom is rotated over the tank and trailer. The RS holds a 4.16 m^3 (1100 gal) tank for self-contained water storage and a second tank can also be added. A separate 7.56 m^3 (2000 gal) tank trailer is used to haul water to the RS.

Components of the RS framework include the rotating turret, attaching framework, boom and hydraulics. The turret is two pieces of IPS-SCH40 pipe with 101.6 mm (4.000 in) outside diameter (O.D.) pipe rotating inside a 114.3 mm (4.500 in) O.D. pipe. The outside pipe is welded to a supporting framework of 127 mm (5 in) channel steel which is bolted to the main frame of the trailer. The boom is two 4.6 m (15 ft) long pieces of 9.84 mm (3 in) channel steel which are pinned at the top of the inside turret pipe. A third 2.5 m (8 ft) piece of channel steel was added between the other two pieces at the trailer end of the boom for added flexure strength. Spacers were positioned and bolted along the boom for stability.

Two different nozzle and pipe frames are currently being used. One frame consists of nine nozzles in a three by three array (figure 1) with approximately two meter nozzle spacing. Another is a four nozzle, two by two array with a 2.5 m (8 ft) enclosure to minimize evaporation and drift (figure 2), which is used for doing sprinkler infiltrometer research. The enclosure frame is made of 13.7 mm (0.5 in) electrical conduit with plastic tarp covering the frame. The enclosure consists of two halves, each 1.5 m (5 ft) high, which telescope inside each other in order to fit on the trailer for transport position, as shown in figure 3.

Three hydraulic cylinders are used to: 1.) raise and lower the boom, 2.) rotate the boom between transport and operating positions, and 3.) as a leveling foot (figure 3) at the rear, boom-side corner of the trailer. The cylinders are controlled with hydraulic valves at the rear of the trailer with hydraulic power provided by a closed-loop hydraulic circuit (figure 4) connected to one of the hydraulic connections at the rear of the tractor. The RS frame was designed to have a carrying capacity at the end of the boom of 2.22 kN (500 lb) force with a safety factor of 2. The nine nozzle frame weighs approximately 445 N (100 lb) and the four nozzle frame and enclosure weigh approximately 890 N (200 lb).

The nozzle frames can be attached to a fixed point at the end of the boom (figure 1) or to a rolling carriage that rides on top of the boom (figure 2). The rolling carriage is attached to a cable and pulley system and can move in or out 1.2 m (4 ft) for easier positioning over field plots. The carriage consisted of four steel caster wheels and a hanging frame and connection joint that rides between the two pieces of channel steel of the boom.

Water and air are supplied to the nozzle with 16 mm (5/8 in) rubber garden hose and 9.5 mm (3/8 in) clear vinyl tubing, respectively. Separate radial manifolds are used for water and air distribution, as suggested by Shelton et al (1985). Supply lines to the manifolds were 38 mm (1.5 in) plastic suction hose for water and 19 mm (3/4 in) rubber garden hose for air.

Nozzles used with this RS are Spraying Systems[1] Fulljet HH30WSQ with nozzle pressures of approximately 20 kPa (3 psi) which produce a full range of drop sizes up to 6 mm (1/4 in) and when operated from a height of 3 m (10 ft) exhibit impact velocities within two percent of their respective terminal velocities (Shelton et al, 1985). Christiansen's (1942) distribution uniformity coefficients are generally greater than 80 percent as measured by the author and by Shelton et al (1985).

Water flow to each nozzle is less than or equal to 6.8 lpm (1.8 gpm). Application rates of 50 to 100 mm/hr (2 to 4 in/hr) are obtained with these nozzles. Other nozzles in the Spraying Systems Fulljet HH--WSQ series can be used for other ranges of application rates. When the nine nozzle frame is used, a second 1.51 m^3 (400 gal) tank is added for 5.67 m^3 (1500 gal) total water storage which allows the RS to be operated at least 90 minutes between refilling.

An adaptation to each nozzle assembly was to insert a piece of 6.3 mm (0.25 in) O.D. plastic tubing that fit tightly inside the 9.5 mm (3/8 in) air inlet hose barb, which is shown in figure 5. This piece of tubing has a 3 mm (0.12 in) inside diameter and provided for better air injection by having a greater pressure gradient at the point of injection. Greater pressures in the air lines reduce the risk of water migrating up the air lines and interfering with air flow. Without this alteration, water sometimes moved up some of the air lines, stopping air flow entirely in those lines with all of the air going to the other nozzles.

Water is pumped with a 250 W (1/3 HP) 120 V AC water pump powered by a gasoline-powered electrical generator that is carried on the trailer. A vertical, tapered-tube and float type 1.91 lps (30 gpm) capacity flowmeter and gate valves are used to control and monitor water flow. Air is supplied with a 3.7 kW (5 HP) gasoline-powered air compressor and tank, also carried on the trailer. The air compressor supplies up to 3.8 lps at 276 kPa (8 cfm at 40 psi). A separate tapered-tube and float, 5 lps (10.5 cfm) capacity flowmeter and valves are used to monitor and control air flow.

<u>Operation</u>

The Akron USDA-ARS rainfall simulator works well for watering 4 m (13 ft) square plots with the nine nozzle frame and 1.5 m (5 ft) square infiltration frames with the four nozzle frame and enclosure. The slightly larger 2.5 m (8 ft) enclosure allows the soil outside of a smaller infiltration frame to be watered similar to a double-ring infiltrometer, so that more accurate infiltration values are measured. A vacuum extraction system similar to one developed by Kelso (1982) is used to remove any non-infiltrated water, collect it in a tank, and measure the volume of collected runoff water over time.

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1. Note: The mention of trade names or commercial products does not constitute their endorsement or recommendation for use by the Agricultural Research Service of the U.S. Department of Agriculture.

The nine nozzle frame without an enclosure works satisfactorily in winds up to 16 km/hr (10 mph) by using the rolling carriage and rotating the boom to position the nozzle frame to compensate for wind drift of the water drops. Typical times for initial setup next to a plot is 5 minutes and movement to adjacent plots is 3 minutes, all using just one person at the rainfall simulator. One improvement planned for the RS is to add a hydraulic cylinder and cable system for raising and lowering the lower half of the four nozzle enclosure.

Summary

A rainfall simulator was constructed based on the existing design of Shelton et al (1985) but with improved portability, air injection, water storage and easier interchanging of nozzle arrays for different research uses. It consists of a flat bed trailer carrying water tanks for on board water storage and a rotating turret and boom constructed of pipe and channel steel that is attached to the rear of the trailer. The boom is rotated to one side of the trailer for applying water to plots and positioned over the trailer and water supply tanks for road transport. Hydraulic cylinders are used to control the boom with hydraulic power provided by a tractor that also pulls the trailer. Interchangeable spider-like frames that hold the nozzles are suspended from the end of the boom. The simulator can apply water at rates up to 100 mm/hr (4 in/hr), which for the 3 by 3 nozzle array is 1 lps (16 gpm), for at least 90 minutes before refilling is needed.

A nine nozzle (3 x 3) array is used to water 4 m (13 ft) square plots and a four nozzle (2 x 2) array with a wind-protection enclosure is used as part of a sprinkler infiltrometer. The enclosure also fits on the trailer for transport. Better positioning of the nozzles over the plots is possible by rotating the boom and by using a rolling carriage that rides on top of the boom and holds the nozzle frames. Water can be applied in winds up to 16 km/hr (10 mph) without a wind-protecting enclosure. Typical time for set up is five minutes and movement to adjacent plots is three minutes. A gasoline-powered air compressor and generator are carried on the trailer to provide air and electricity for a water pump, respectively.

References

Bubenzer, G. D. 1979. Inventory of rainfall simulators. In Proceedings of the Rainfall Simulator Workshop. ARM-W-10. Science and Education Administration, U.S. Dept. of Agriculture, Washington D.C., pg. 120-130.

Christiansen, J. E. 1942. Irrigation by sprinkling. University of California, Berkeley. Bulletin 670:86-91,100-16.

Kelso, G. L. 1982. A system for measuring infiltration rates under center pivot irrigation systems. Masters Thesis, University of Nebraska, Lincoln.

Shelton, C. H., R. D. von Bernuth, S. P. Rajbhandari. 1985. A continuous-application rainfall simulator. Trans. of the ASAE 28(4):1115-1119.

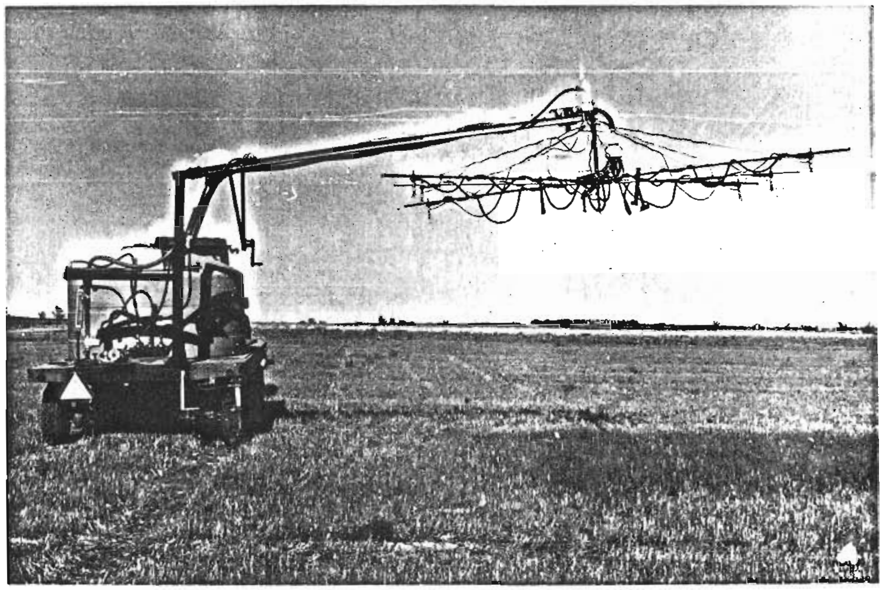

Figure 1. Rainfall simulator with the nine nozzle frame and the boom rotated in the operating position.

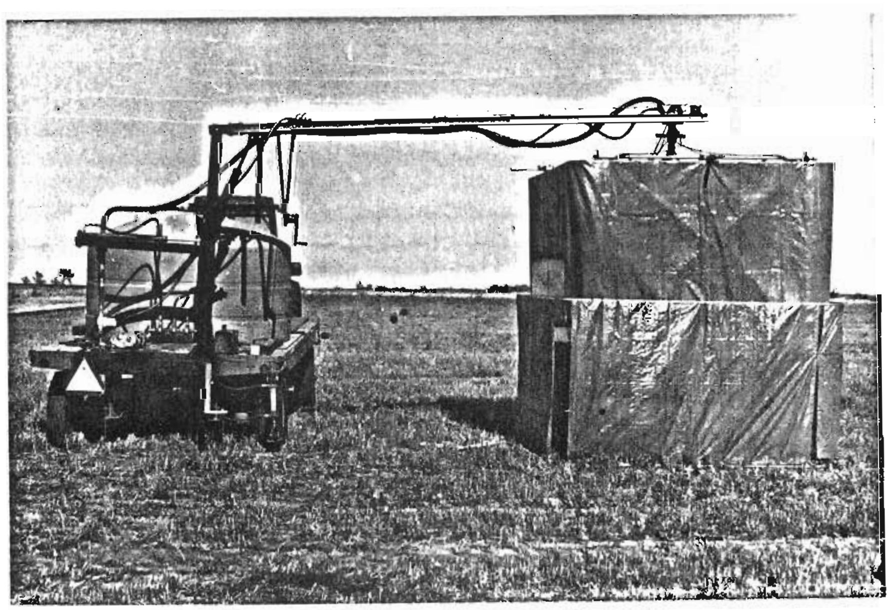

Figure 2. Rainfall simulator with the four nozzle frame and wind protection enclosure in operating position.

Figure 3. Rainfall simulator with the four nozzle frame and enclosure in transport position.

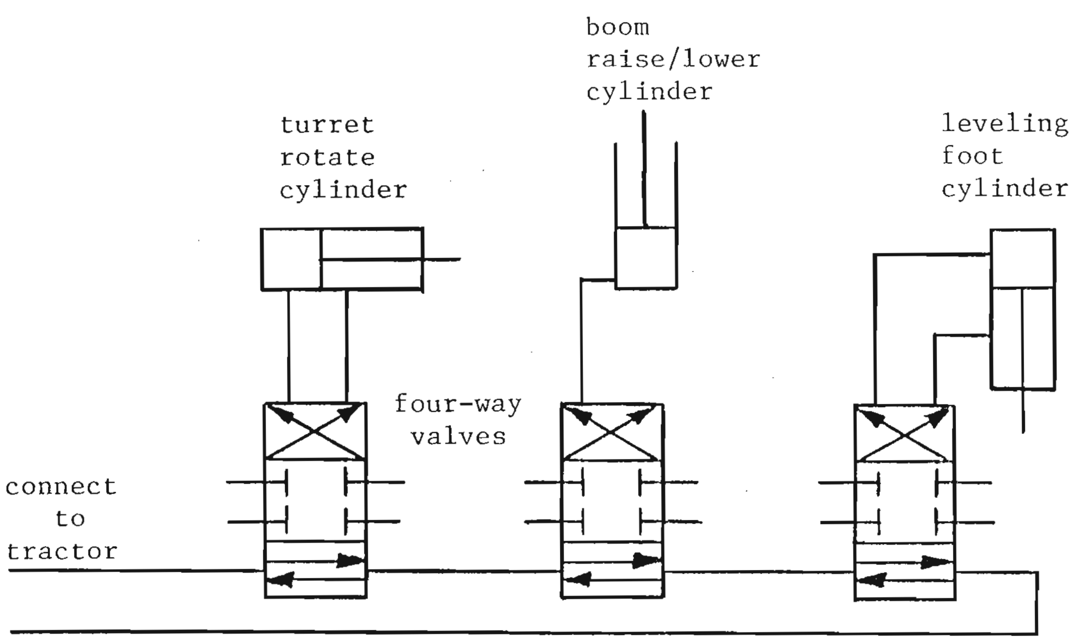

Figure 4. Closed-loop hydraulic circuit used to power the rainfall simulator.

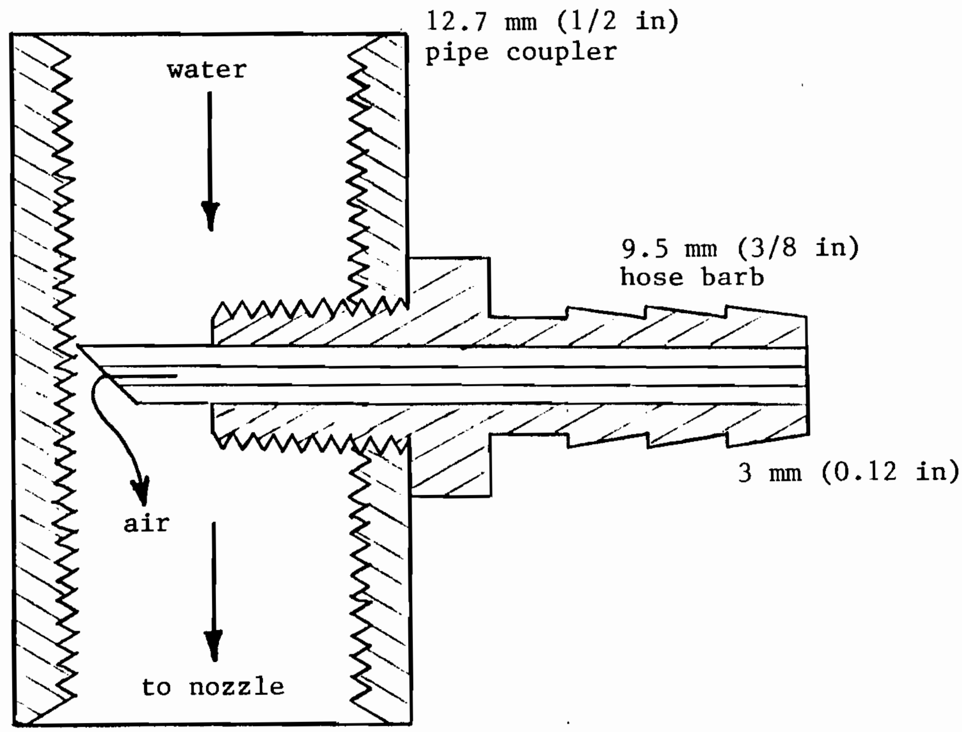

Figure 5. Air injection connection showing the plastic tubing inserted inside of the air line hose barb.