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# Emitter Discharge Sensitivity to Water Temperature

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**Abstract:** The nozzle type emitters of rated discharge 4 L $h^{-1}$ and 8 L $h^{-1}$ with Pressure Compensating (PC) and Non-Pressure Compensating (NPC) mechanisms and four different diameter microtube emitters, ranging from 1.20 to 1.77 mm, were tested in a laboratory to determine the sensitivity of their flow rates to temperature variation. The sensitivity of emitter discharge to temperature was determined for water temperature ranging from 20°C to 60°C (68°F to 140°F) at a line pressure of 1.00 kg $cm^{-2}$ for emitters and 0.6 kg $cm^{-2}$ for microtubes. The discharge rates ranging from 6.842 L $h^{-1}$ to 7.6293 L $h^{-1}$ were observed in different diameter microtubes. The experimental results indicated linear relationship of emitter and microtube discharges at various water temperatures at a given line pressure. The percentage discharge variation ranging from 53 to 56% with relative flow rate increase at a constant rate of 1.56% per °C was observed for all microtube emitters tested, irrespective of their diameters in the water temperature range of 20 to 60°C. The discharge variation was observed to be 4.62%, with a maximum relative discharge rate increase of 0.115% per °C for NPC emitters whereas for PC emitters, these were 1.53% and 0.038% per °C in the same range of water temperature, respectively. The design consideration should, therefore, include temperature-induced discharge variations to ensure uniformity of water application.

**Key words:** Trickle irrigation, water temperature variation, emitter discharge, PC and NPC emitter, microtube emitters, relative flow rate.

One of the major requirements of trickle irrigation is precise control of water application rate. To attain the optimum control, all emitters must deliver water at equal rates, and rate should not change with time or environmental factors. Design standards recommended a maximal 10% variation in emitter discharge along an irrigation line and over the field (Bucks and Myers, 1974; Keller and Karmeli, 1974; Wu and Gitlin, 1974). In the design of an irrigation network, emitter discharge is traditionally assumed to be a function of pressure only. However, an additional factor, which could result in large emitter discharge variations is water temperature variation. Temperature exercises its influence by changing the viscosity of water flowing in the system. Viscosity changes due to changing water temperature, cause emitter discharge variations greater than the maximum ±10% limit, if flow through emitter is laminar. Turbulent flow emitters, on the other hand, are not affected by viscosity changes.

Trickle irrigation lines installed on the soil surface are subjected to temperature changes by convection and radiation due to ambient temperature and direct sunshine, respectively. This change of temperature of trickle lines will affect the water temperature in the line. These temperature variations can occur in a number of ways.

Temperature variation occurs over a period of time with day-night, day to day and seasonal weather changes and from end to end of lateral lines due to solar heating of black plastic pipe. Water temperatures in lateral lines as high as 77°C (170°F) have been reported (Anonymous, 1975). The water temperature variation along the line will affect the hydraulic performance of both emitters and trickle irrigation lines.

There are very few research results regarding the effect of temperature on trickle irrigation lines and emitter hydraulics. Keller and Karmeli (1974) have listed the theoretical discharge variations based on viscosity changes for the temperature range 5 to 40°C (41 to 104°F). Parchomchuk (1976) reported test results for different trickle irrigation emitter such as spiral passage, microtubes, orifice and vortex emitters and showed maximum discharge variation of 23 to 53% in temperature range 5 to 60°C for a 0.635 mm diameter microtube emitter with a discharge rate of 1.21 L $h^{-1}$ at 20°C. Zur and Tal (1981) developed a linear relationship between emitter flow and temperature for different types of emitters. They also showed a combined effect of pressure and temperature for different types of emitters and emitter discharge. Peng *et al.* (1986) indicated that the temperature effect on the shape of energy gradient was found to be insignificant. They also found that a temperature difference ranging from ± 20 to 50°C along the line caused approximately 1 to 2% difference (of the total friction $\Delta H_L$) at the middle section of the lateral line. Wu and Phene (1984) concluded that the effect of temperature on emitter flow depends upon the type of emitter. Kadale *et al.* (1992) established temperature-discharge relationship for different diameter microtubes. They concluded that sensitivity to temperature increased with operating pressure head.

The objective of the present investigation was to measure the discharge sensitivity to temperature variation of emitters and microtubes of different diameters, and to investigate the relative importance of temperature distribution on discharge distribution of these emitters.

## Materials and Methods

Six nozzle type emitters, characterized by flow rate (4 L $h^{-1}$ and 8 L $h^{-1}$) and pressure dissemination mechanism (i.e., Pressure Compensating and Non-Pressure Compensating) and four microtube emitters of different diameters (1.20, 1.25, 1.45 and 1.77 mm) were used in the present study. The microtube length selected for the study was 60 cm (1.97 ft).

The temperature sensitivity of emitter discharge was determined for each of the aforementioned emitters. The emitter field consisted of two laterals (each 16 mm internal diameter and 10 m length), equipped with ten emitters of same kind at a spacing of 1.0 m. With this arrangement, 20 emitters could be tested at one time for one temperature. To perform the test, pump was activated and pressure was adjusted by setting the pressure relief valve, which was located directly downstream from the pump. The pump was allowed to run until equilibrium was established, i,e., pressure gauge located next to the filed showed a constant reading. Then the water of desired temperature was passed through the system and the cans of 1000 ml capacity were slide beneath the emitter field for a set of 5 minute interval, and the accumulation of water in each can

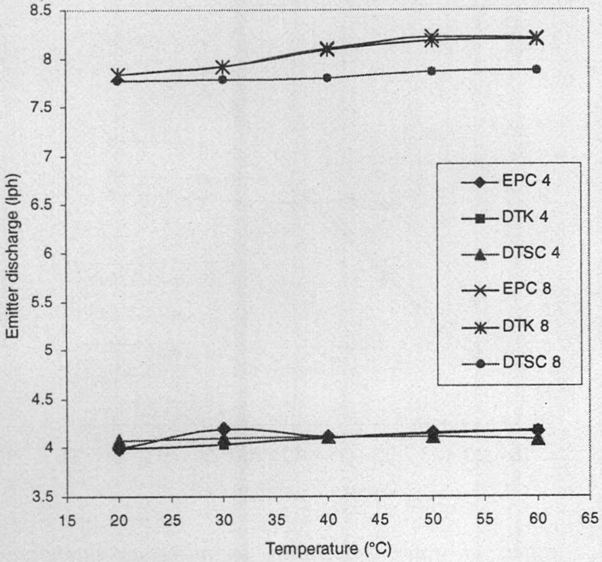

*Fig. 1. Effect of water temperature on emitter discharge.*

was measured and recorded. Each test was replicated thrice. The data was used to determine the discharge sensitivity of nozzle emitters and microtube emitters to water temperature variation. Mokashi *et al.* (1997) confirmed that the pressure of 1.0 kg cm$^{-2}$ is optimum for operating trickle irrigation with emitters and 0.6 kg cm$^{-2}$ with microtubes. Thus, flow rates were measured at different temperatures from 20 to 60°C (68 to 140°F) at an operating pressure of 1.0 kg cm$^{-2}$ for emitters and 0.6 kg cm$^{-2}$ for microtubes and the laterals were placed at 0% slope. Water temperatures above ambient were obtained by mixing tap water with hot water from an immersion electric heater in various proportions. Water temperatures below ambient were obtained by passing tap water through pipe immersed in a container filled with ice water. Water temperatures were measured at each outlet on the lateral line, which showed the temperature difference between the first and the last emitter, not exceeding 2°C (35°F).

## Results and Discussion

The experimental results of nozzle emitter and microtube emitter flow rates at various water temperatures indicated that discharge of NPC emitters and microtube increased with increase in water temperature, but the similar trend was not observed in PC emitters. The flow rate remained approximately constant with the increase in water temperature (Fig. 1 and 2). Using 20°C (68°F) as the standard operating water temperature, percentage variation of discharge at this temperature was calculated and plotted in Fig. 3 for microtube emitters and in Fig. 4 for PC and NPC emitters. Fig. 3 also shows the predicted effect of viscosity change with temperature on percentage variation, characteristics of laminar flow (Keller and Karmeli, 1975).

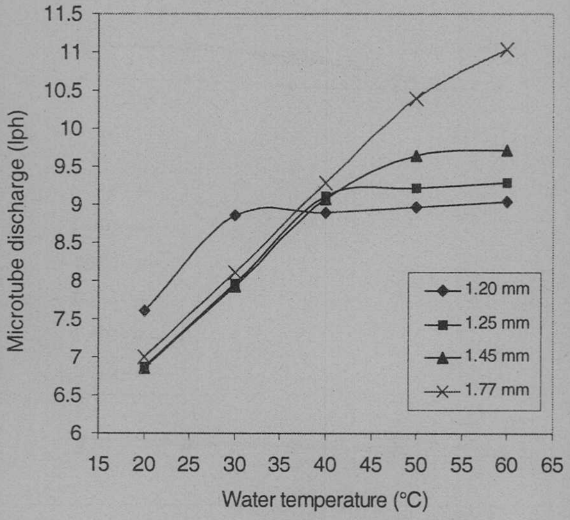

*Fig. 2. Effect of water temperature on microtube discharge.*

### *Microtube emitters*

Small diameter microtube emitters have recently been introduced in place of emitters, to overcome the plugging associated with nozzle type emitters. They are economical compared to the emitters. The microtube emitters of different diameters operated at 0.6 kg cm$^{-2}$ showed the percentage discharge variation ranging from 53 to 56% for the temperature range of 20 to 60°C. The discharge rate of 6.842 L h$^{-1}$ to 7.6293 L h$^{-1}$ was observed in different diameter microtube emitters. The results in Fig. 3 indicate that the increase in temperature causes increasing rate of discharge up to a certain value, but thereafter a steady discharge is obtained, which showed inability to increase in discharge rates with temperature increase. The relative discharge rate increased at a constant rate of 1.56% per °C for all microtubes tested regardless of their diameters (Fig. 3). Note that this increase is considerably less than the theoretical rate due to viscosity change, 2.80% per °C. But at certain temperature, a break in the curve occurs and further temperature increase causes little or no increase in discharge rates. This break occurs at 32°C for microtube of 1.20 mm diameter

*Table 1. Microtube emitter data*

| Microtube diameters (mm) | Operating pressure (kg cm$^{-2}$) | Discharge rate at 20°C (L h$^{-1}$) | Transition temperature | | Reynolds number ($R_N$) at transition temperature |
|---|---|---|---|---|---|
| | | | °C | °F | |
| 1.20 | 0.6 | 7.6293 | 32 | 90 | 2800 |
| 1.25 | 0.6 | 6.8810 | 40 | 104 | 2950 |
| 1.45 | 0.6 | 6.8420 | 45 | 113 | 2580 |
| 1.77 | 0.6 | 7.0011 | 54 | 129 | 2840 |

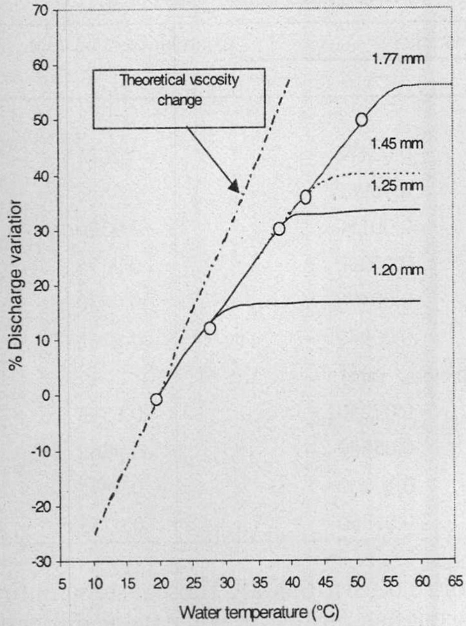

*Fig. 3. Discharge variation of microtube relative to discharge variation at 20°C.*

and at 54°C for 1.77 mm diameter. As noted in Table 1, the Reynolds numbers ($R_N$) at this transition point are 2000-3000, indicating that flows are at upper limit of laminar flow. Turbulent flow occurs at temperatures above this point. The data indicates that the transition point is reached earlier as the diameter of microtube is reduced. This may be due to dependency of Reynolds number ($R_N$) on the velocity of flow and diameter of the flow path. Since the maximum variation in discharge is limited by the transition to turbulent flow, discharge variation can be decreased by causing turbulent flow to occur at lower temperatures. This can be accomplished by increasing the discharge rate or decreasing the tube diameter for a given discharge rate.

### *PC and NPC emitters*

Theoretically, the emitter discharge is independent of water temperature (viscosity), but in practice, flows are slightly viscosity- dependent due to the length of flow path in these emitters. As with microtube emitters, the discharge rate in NPC type emitters increased linearly with temperature, but at a slight variation of 4.62% for 20 to 60°C temperature range, if the variation at 20°C is considered as zero per cent. The PC emitters showed a very negligible discharge variation of 1.53% in the same range of temperature. The average rate of increase in discharge of NPC emitters was found to be 0.115% per °C, while that of PC emitters was very slight i.e., 0.038% per °C (Fig. 4 and Table 2). The very low increase in flow rate of PC emitters with temperature change indicated the better resistance of resilient material inside the emitters. The flow in

*Table 2. Flow rates of emitters as affected by temperature*

| Temperature (°C) | Type of emitter with average discharge (L $h^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | DTK-4 (NPC) | DTSC-4 (PC) | DTK-8 (NPC) | DTSC-8 (PC) | EPC-4 (NPC) | EPC-8 (NPC) |
| 20 | 3.9783 | 4.0639 | 7.8400 | 7.7136 | 3.9717 | 7.8302 |
| 30 | 4.0140 | 4.0943 | 7.9144 | 7.7791 | 4.0126 | 7.9069 |
| 40 | 4.0956 | 4.1146 | 8.0790 | 7.8100 | 4.0908 | 8.0807 |
| 50 | 4.1360 | 4.1228 | 8.1496 | 7.8250 | 4.1250 | 8.1277 |
| 60 | 4.1573 | 4.1248 | 8.2060 | 7.8370 | 4.1516 | 8.1903 |

*Table 3. Experimental values of constants m and n for various emitters and microtubes*

| Emission device | Regression constants | | Coorelation constant (r) |
|---|---|---|---|
| | m | n | |
| Emitters | | | |
| DTK 4 (NPC) | 3.8850 | 0.00476 | 0.9821 |
| DTK 8 (NPC) | 7.6509 | 0.00960 | 0.9825 |
| DTSC 4 (PC) | 4.0439 | 0.00150 | 0.9320 |
| DTSC 8 (PC) | 7.7929 | 0.00290 | 0.9375 |
| EPC 4 (NPC) | 3.8814 | 0.00470 | 0.9830 |
| EPC 8 (NPC) | 7.6507 | 0.00940 | 0.9765 |
| Microtube emitters (represented in terms of inner diameters, mm) | | | |
| 1.20 | 5.7050 | 0.07250 | 0.9548 |
| 1.25 | 6.1172 | 0.05880 | 0.9862 |
| 1.45 | 5.1041 | 0.10000 | 0.9945 |
| 1.77 | 7.5230 | 0.02860 | 0.9753 |

these emitters is non-linear, thus there is no transition point.

### *Correlation between emitter discharge rate and water temperature*

The experimental results of nozzle emitter and microtube discharge at various temperatures at a given line pressure suggest that the discharge-temperature relationship for the tested emitters are essentially linear and could be described by the following equation:

$$Q = m + nT \qquad ...1$$

in which m and n are regression constants, Q is the emitter discharge rate in L $h^{-1}$ and T is the water temperature in °C. The constants m and n, computed by a linear regression analysis of the results, are presented in Table 3 for the various emitters and microtubes. From Table 3, it is clear that discharge sensitivity to temperature, as expressed by n, is quite more in microtubes as compared to emitters. Further, the discharge sensitivity to temperature of PC emitters was very negligible, ranging from 0.0015 to 0.0029. These results confirm the earlier results of percentage discharge

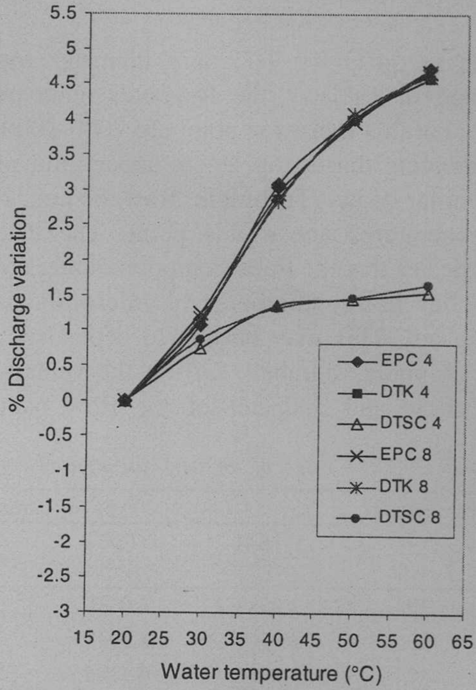

*Fig. 4. Discharge variation of emitters relative to discharge at 20°C.*

variation and relative discharge rate for all the emitting devices.

## Conclusions

Discharge variation through different emitting devices by changes in viscosity of water due to temperature was studied. The discharge variation was very negligible in case of PC emitters. Since the maximum discharge variation in microtubes is limited by transition to turbulent flow, the temperature- caused discharge variation can be decreased by causing turbulent flow at lower temperatures, i.e., either by increasing the discharge rate or decreasing the tube diameter for a given discharge rate. To achieve precise and uniform application of water, temperature caused variation must be considered in design and the system be operated under conditions which ensure minimum water temperature variation from 20°C.

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