The problem of percolation of fluids through porous materials has been attempted in a number of ways by the research workers of this field. Some have tried to give a theoretical solution of the problem while others have used various analogies to give a semi-empirical solution of the problem. In the present investigation pipe flow analogy has been adopted and attempt is made to find an answer to discrepancy between the critical Reynolds number for flow through straight pipes \( (Re_c \approx 2000) \) and porous media \( (Re_c \approx 1 \text{ to } 10) \).

The various important works related to porous media flow and pipe flow have been reviewed and the causes of non-linearity in flow through porous masses have been studied in detail. An extensive experimental investigation has been conducted to study the effect of the following factors on critical Reynolds number.

(i) Curvature of flow paths (in unidirectional).
(ii) Continuous changes in the direction of flow along curved paths; and
(iii) Changes in the cross-sectional areas of flow channels along the direction of flow.

Models made of copper tubes are employed in the above experimental investigation. Tubes of five different diameters, i.e. 0.302 cm, 0.45 cm, 0.595 cm, 0.817 cm, and 1.033 cm have been used for first three cases, i.e. straight lines, uni-directional curved flow and sinusoidal flow.

These copper tubes have been tested in a straight state as well, so as to check their circularity and straightness. The
Experimental results show a slight dependence of the critical Reynolds number on the diameter of the tube, i.e., the critical Reynolds number decreases slightly with an increase in the pipe diameter. This effect has been found to be present in other models as well, i.e., unidirectional flow along curved paths and sinusoidal flow.

To study the effect of curvature on critical Reynolds number, hydraulic tests have been conducted on all the five tubes at various radii of curvatures ranging from 0.5 m to 25 m with unidirectional flow.

The results of these hydraulic tests show a deviation from linear law before the actual turbulence in flow starts. The change from laminar to turbulent flow is found to be gradual against a sudden change in case of straight tubes and the critical Reynolds numbers decrease with an increase in the curvature of flow paths. The critical Reynolds number for flow along a curved path is found to be dependent on the diameter of the flow channel besides its curvature.

To investigate the effect of change in the direction of flow along a curved path on critical Reynolds number, models consisting of sinusoidal circular curves with various radii of curvatures ranging from 0.5 m to 4 m have been used. All the five copper tubes mentioned above have been employed for these models. The results of hydraulic tests on these models, where curvature is combined with change in the direction of flow, also indicate a gradual change in the regime of flow. The changes in the flow direction further reduce the critical Reynolds number when compared to the results of model 1, i.e., unidirectional flow at...
the same radius of curvature.

For a study of the effect of changes in the cross-sectional areas of the flow channels along the direction of flow on change in the regime of flow, i.e. from laminar to turbulent, models consisting of a series of expansions and contractions have been used. These are made from pieces of copper and aluminium tubes of various diameters, i.e. 1.201 cms, 0.817 cm, 0.595 cm, 0.45 cm, 0.302 cm and 0.201 cm. Models with various diameter ratios \( \frac{d_1}{d_2} \) ranging from a maximum of 5.080 to a minimum of 1.250 have been employed to establish a relationship between the critical Reynolds number and the ratio of the diameters of the two tubes constituting the model.

Here, \( d_1 = \) diameter of the bigger pipe.

\[ \text{d}_2 = \text{diameter of the smaller pipe.} \]

The experimental results of model 3, i.e. a series of expansions and contractions, also show a early departure from laminar flow as in previous cases. The critical Reynolds number is found to be decreasing with an increase in the diameter ratio \( \frac{d_1}{d_2} \). The effect of expansions and contractions in the flow paths on critical Reynolds number appears to be more than that due to curvature or curvature combined with changes in flow direction.

The ranges of Reynolds numbers covered for the various models are as follows:

- Straight tubes 25 to \( 10^4 \).
- Model 1 (uni-directional flow) 25 to \( 10^4 \).
- Model 2 (sinusoidal flow) 25 to \( 10^4 \).
- Model 3 (expansion - contraction type model) 20 to \( 3 \times 10^4 \).