Performance Evaluation of a Metal Fractal Liquid Distributor

A research report
written for purposes of

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by

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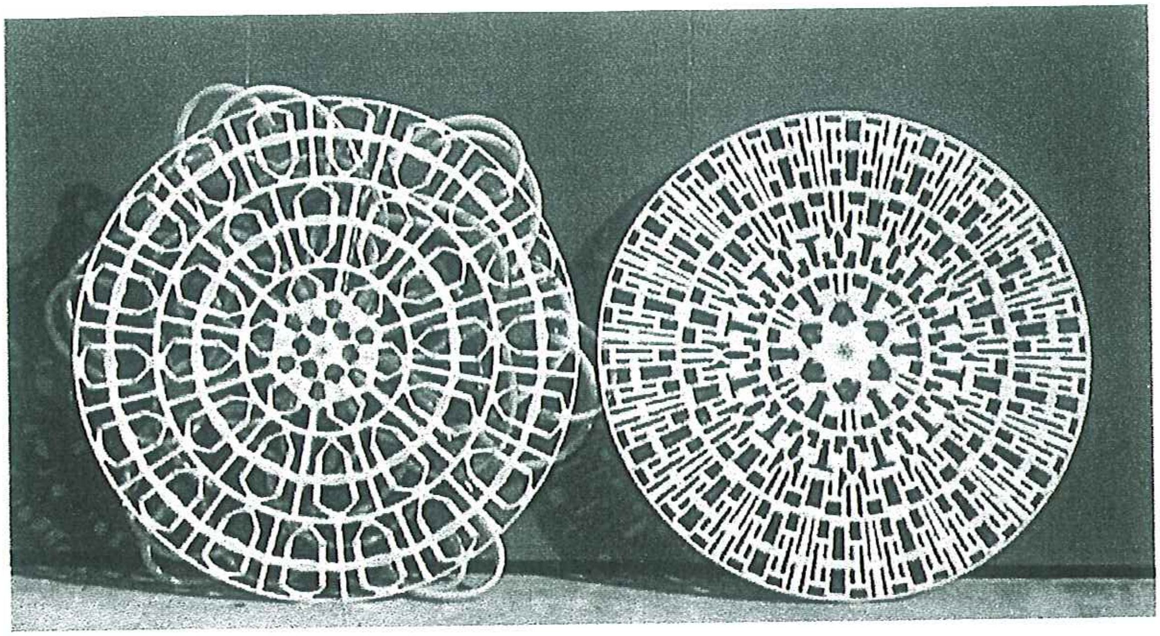
Summary

Our earlier effort has proven that a fractal geometry based liquid distributor for packed columns offers the potential for achieving the highest quality of liquid distribution over a wide range of liquid load, independent of column diameter. However, fractal distribution plates manufactured from polypropylene are not suitable for common distillation applications. Therefore, an attempt has been made to develop a metal version, which resulted in a Y-shaped, narrow trough like liquid distribution compartment with three drip pipes. A pilot scale prototype comprising six liquid distribution compartments has been manufactured and tested. Water test data are presented for various liquid loads indicating a superior performance with respect to that of a conventional narrow trough distributor of the same size.

INTRODUCTION

Proper performance of random or structured packing, particularly material with a large specific area, requires a highly efficient initial liquid distribution. This implies utilization of liquid distributors with a rather large number of symmetrically distributed drip points with a variation in individual flows below 10% (Moore and Rukovena, 1987, Perry et al, 1990). To achieve these goals in practice with an economical cost, however, is not an easy task (Nutter and Silvey, 1991).

In an earlier report to ARI (Olujic, 1997) and a paper by Kochergin et al (1997), we have shown that a high quality liquid distribution can be implemented in practice by adopting fractal geometry based approach to design of liquid distributors. Both low and high-density liquid distribution plates (see Figure 1) containing a corresponding number of orifices in the bottom were manufactured from polypropylene. The orifices proved to be prone to fouling and this as well as the complexity, i.e. potentially large costs associated with the manufacture of distribution plates from metal appeared to be major hindrance for a wider acceptance in practice. Therefore, a further effort has been undertaken, which has resulted in development of a metal liquid distributor based on fractal geometry. Basic drawings of a design suitable for 0.45 m ID test column at Delft are shown in Appendix. A prototype, manufactured by TU Delft workshop, has been tested using water and with a slightly pressurized feed proved to be capable of delivering a performance superior to that of a common high performance narrow trough distributor.



94 drip points/m^2 374 drip points/m^2

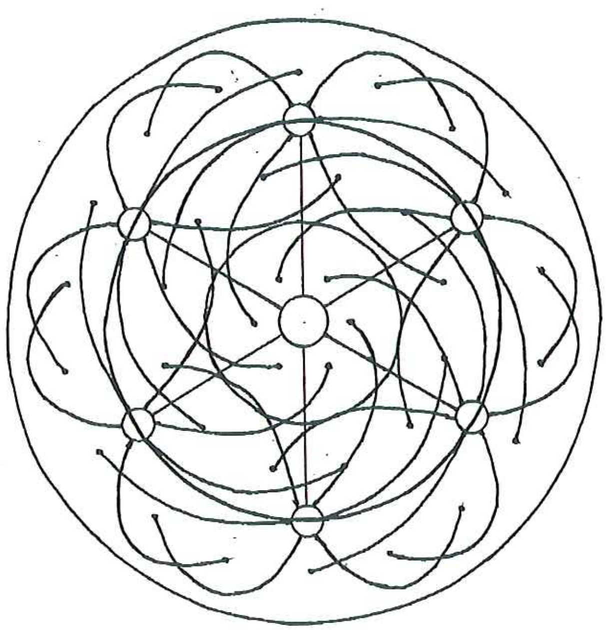


Figure 1 Layout of low- and high drip point density distribution plates of a fractal distributor made of polypropylene for TU Delft column hydraulics simulator (d = 1.4 m), with a schematic illustration of the predistribution manifold

METAL FRACTAL DISTRIBUTOR

The new design is similar to the previous one (Kochergin et al, 1997) in the predistribution stage only. In place of shallow distributor plates with orifices in the bottom, an open, narrow trough like, Y-shaped liquid distribution compartment comprising three drip tubes has been adopted as the basis unit for the new distributor. Photographs of this distributor are shown in Figure 2. Figure 3 illustrates the principal difference in the layout of the fractal distributor and a conventional high performance narrow-trough distributor, both equipped with drip tubes of the same size. The fractal distributor comprises 18 drip

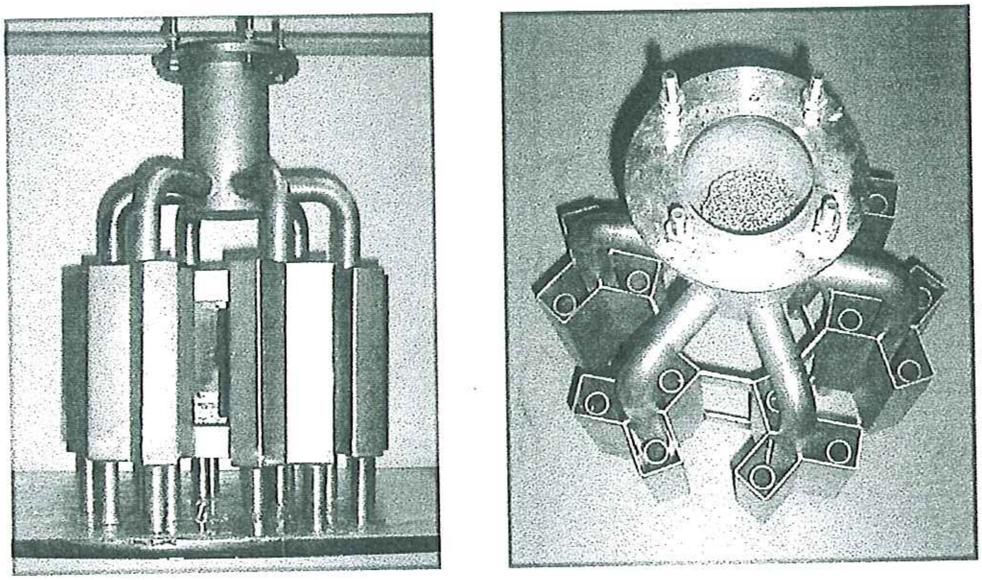


Figure 2 Photographs of the prototype of the metal fractal distributor designed for a 0.45 m ID test column

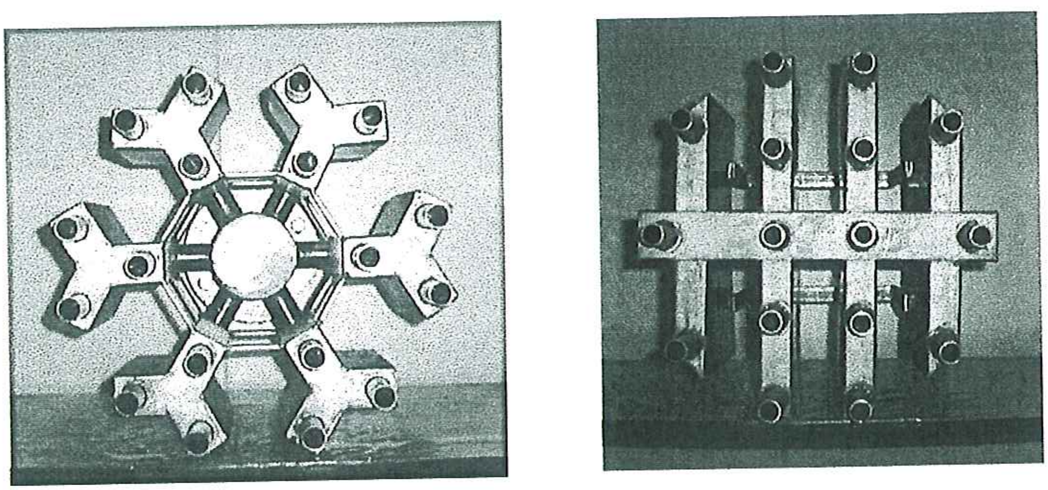


Figure 3 Layout of liquid distribution compartments of metal distributors tested in this study: fractal (left) and narrow trough (right)

tubes, which for the given column diameter (0.45 m) is equivalent to 113 drip tubes per square meter, two more than the narrow trough distributor (100 d.t./m^2). Drip tubes contain orifices with different diameters located at various levels to accommodate the desired large turndown range. In this way a proven narrow trough design allowing high accuracy over a wide range of flows without danger of plugging has been combined with a highly symmetrical predistribution stage.

The same concept can be applied for design of larger diameter distributors, which can be realized by simply adding around the central section concentric ring sections containing adequate number of H-shaped cells each with four drip pipes. As in the case of the polypropylene version the incoming liquid will be distributed via a number of equidistantly placed satellite predistribution cells connected to H-shape distribution cells through flexible tubes of equal length.

RESULTS AND DISCUSSION

Common performance tests have been carried out, by measuring water flow through each drip pipe for a number of liquid loads. A qualitative investigation was carried out by observing the distributor action.

Figure 4 shows the uniformity of distribution obtained with fractal distributor at three liquid loads covering a turndown range of 10 to 1. The accuracy of single drip tubes within each liquid distribution compartment is nearly perfect, as well as overall accuracy at average and high liquid load. At the lowest rate two compartments received respectively more and less liquid than the average, which contributed to a lower overall accuracy. However the corresponding number is still close to the value

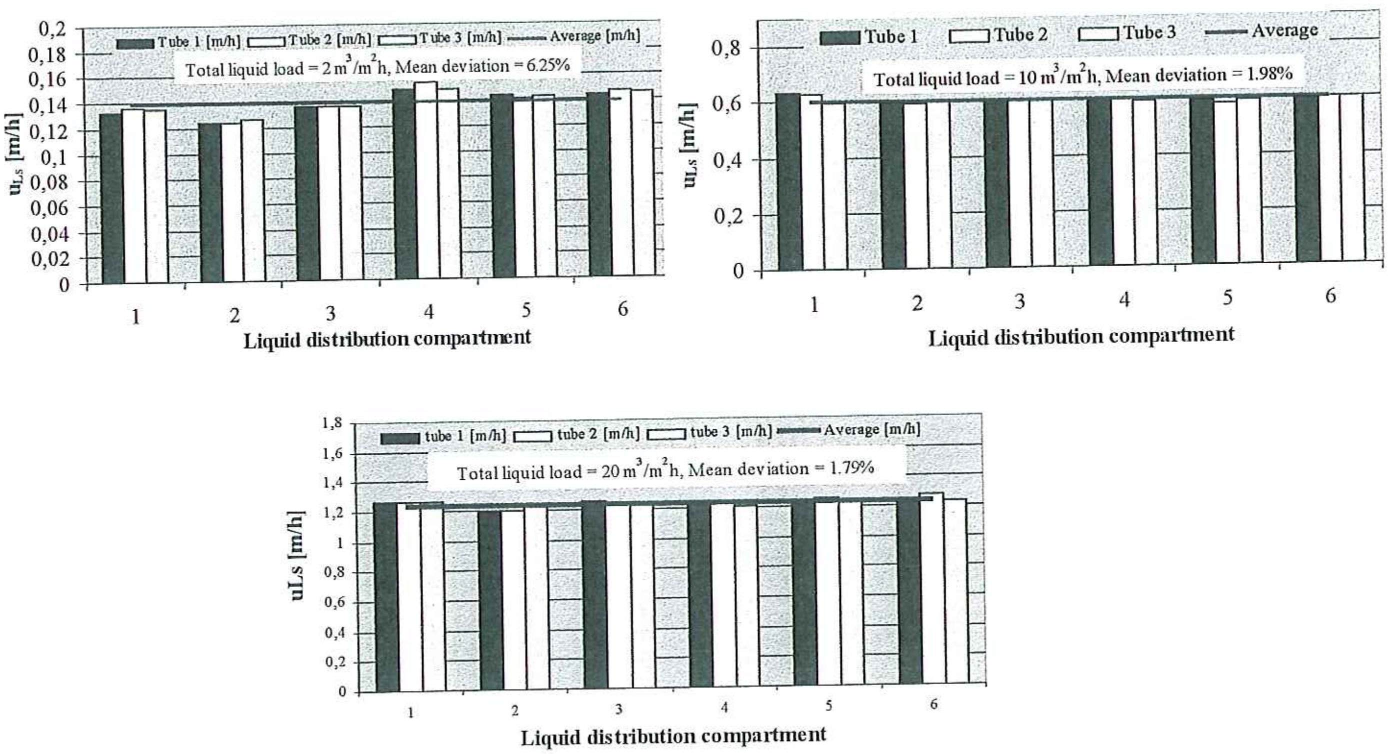


Figure 4 Uniformity of liquid distribution of fractal distributor as a function of liquid load

regarded as high distribution quality. An advantage of drip pipes is that at low rates there is no deviation in the location of the impact of the liquid stream on packing. At liquid loads above the highest rate shown in Figure 4, the liquid commences to maldistribute in the predistributor, most probably because of an insufficient damping effect of inlet calming device (a wire gauze bundle). This indicates that this kind of distributor is extremely sensitive to predistribution. Absence of a connection between compartments eliminates the possibility of any self-correcting action, present in common narrow trough distributors.

Figure 5 indicates that an extraordinary high accuracy can be expected only with a slightly pressurized feed. The source of the deviation in the predistribution stage is most probably in the damping device, i.e. a non-uniform flow resistance due to variation in the porosity of the bundle consisting of woven wire gauze material. However, the observed deviation is still within the range of a high quality distribution, according to present standards.

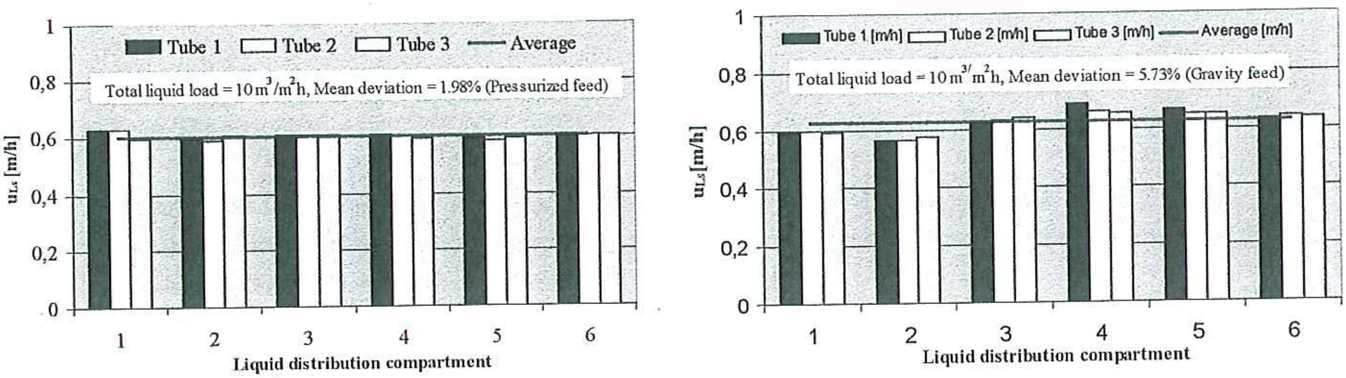


Figure 5 Gravity versus pressurized feed

A comparison with a state of the art narrow trough distributor, shown in Figure 6, indicates the accuracy improvement level attainable with a fractal approach. The sensitivity of the narrow trough distributor to liquid inlet conditions is illustrated in Figure 7.

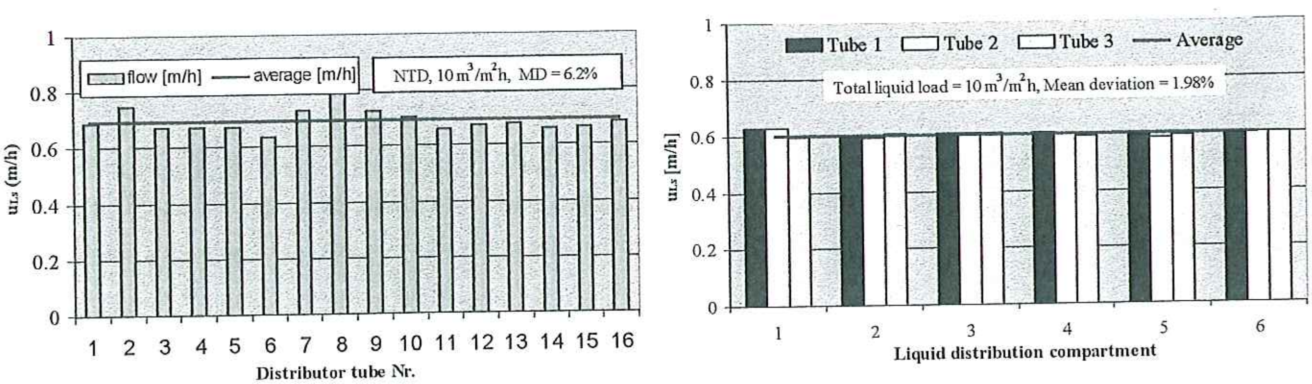


Figure 6 Fractal versus narrow trough distributor

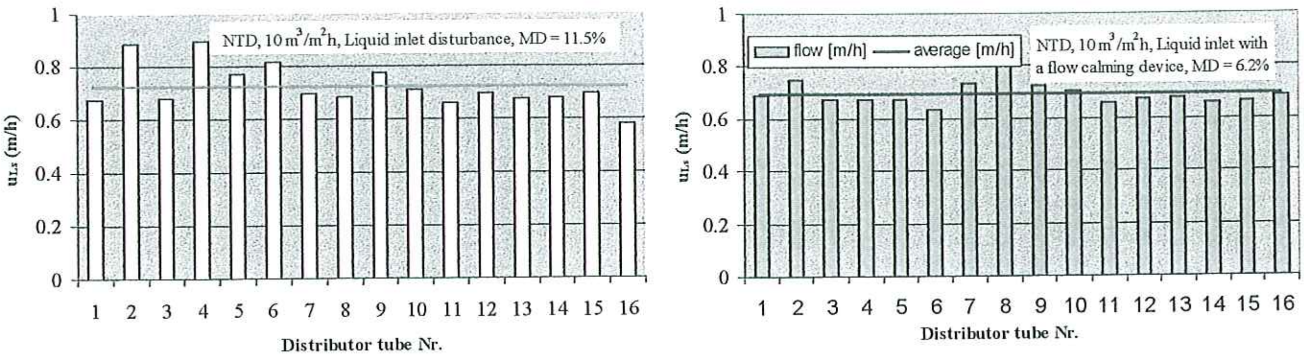


Figure 7 Effect of inlet conditions on performance of a narrow trough distributor

Concluding Remarks

The experimental evidence has demonstrated that a fractal geometry based approach allows design of metal distributors with a uniformity of liquid distribution, which is well above that of common, high performance liquid distributors.

The distribution quality advantage with respect to a narrow trough distributor comes primarily from improved predistribution.

Since the Y-shaped liquid distribution compartments were not interconnected the performance of the fractal distributor proved to be extremely sensitive to the quality of liquid predistribution.

A larger diameter fractal distributor can be realized in metal simply by arranging Y-shape-like narrow trough distribution compartments in the central part and H-shape-like compartments with drip pipes in concentric ring sections.

Although complex at first sight, the structure of a fractal distributor is highly repetitive, which means that a standardized, modular manufacture should not be more expensive than that of common narrow trough distributors.

Manufacture and experimental evaluation of a 1.35 m diameter prototype (size which will fit into the TU Delft packed column simulator) should be revealing in this respect.

Acknowledgement

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References

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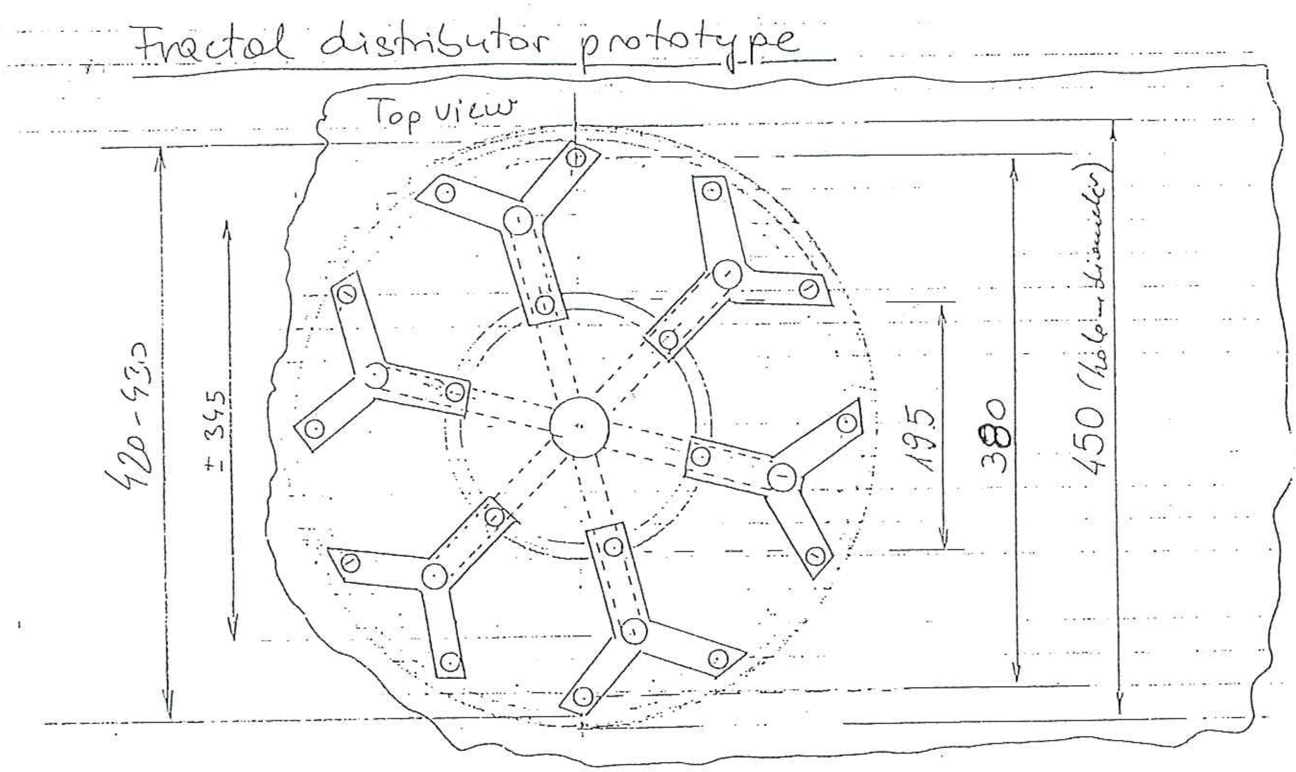
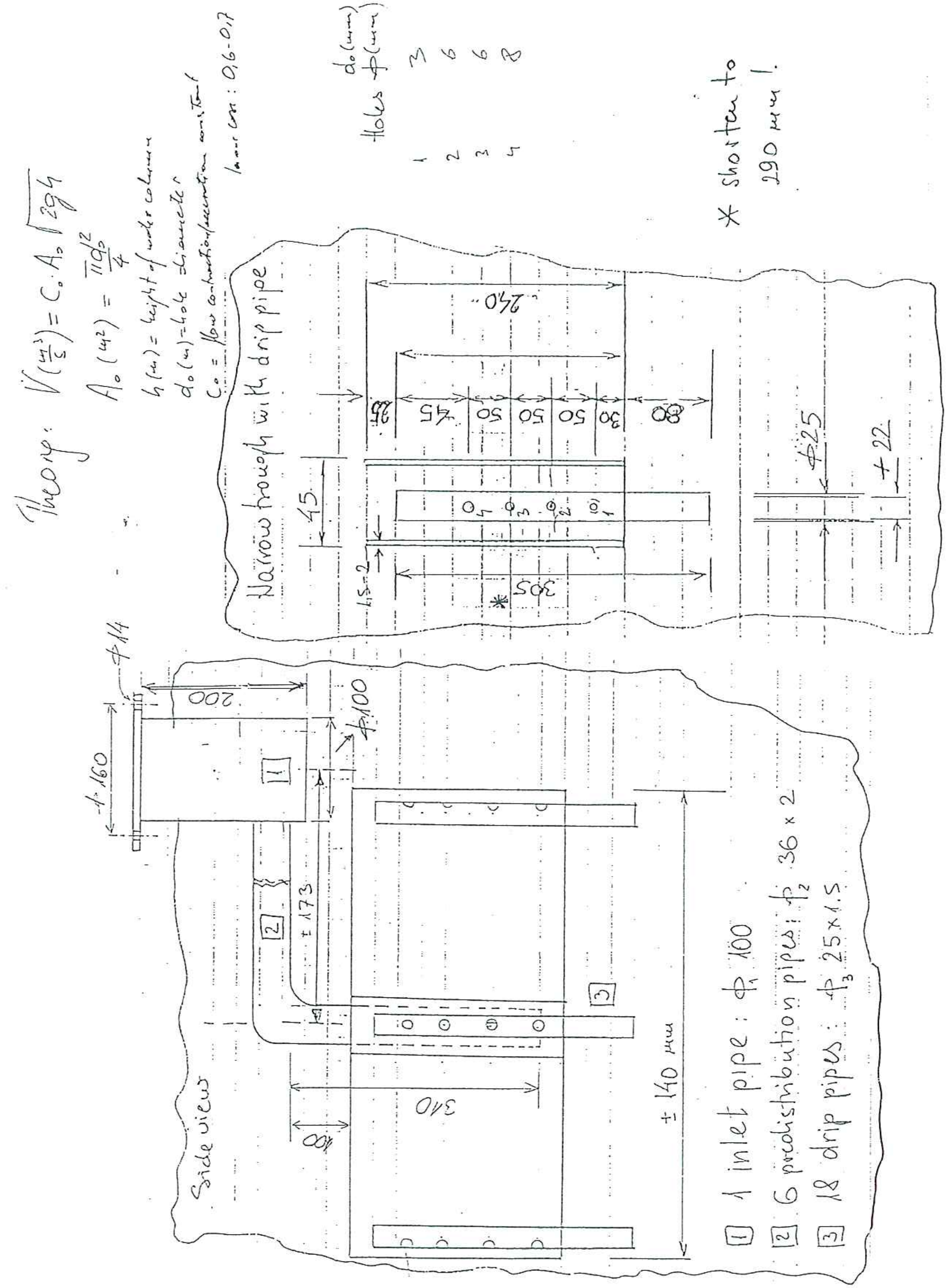
Appendix

Drawings of essential parts of a metal fractal distributor designed to fit into a 0.45 m ID test column.




Theory: V(m³/s) = C₀ · A₀ √(2gh)
A₀ (m²) = πd₀²/4
h (m) = height of water column
d₀ (m) = hole diameter
Holes d₀ (mm)
1 3
2 6
3 6
4 8
* shorten to 290 mm!
Narrow trough with drip pipe
240
305
Side view
340
± 140 mm
200
1 inlet pipe: Φ₁ 100
6 predistribution pipes: Φ₂ 36 x 2
18 drip pipes: Φ₃ 25 x 1.5