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Gamma Scanning a Column Containing Closely Spaced Trays

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ABSTRACT

Gamma scanning of distillation columns has become commonplace in the CPI. It may be utilized to determine tray location and proper installation. Distillation columns may also undergo gamma scanning during operation. The scan is able to provide rough estimations of froth heights, downcomer liquid level, tray flood, potential tray damage, and to depict operational profiles of transition sections and distributors. The 90° orientation of successive closely spaced UOP MD™ trays, coupled with the amount of metal due to fasteners and associated hardware, produces difficulties when columns containing these trays are scanned. UOP and Synetix (ICI Tracerco) worked together to gain a better understanding of how to most effectively scan a column containing MD trays and how to interpret the results of the scan.

INTRODUCTION

Gamma scanning has become a popular distillation column diagnostic tool. It allows inspection of the column internals without interrupting operation. A collimated beam of gamma rays passes through the column wall, is affected by the column internals and hydraulic conditions, and passes through the other side. By measuring the intensity of the radiation exiting the column, one is able to determine the density of the material through which the radiation passed. The higher the density of the material, the lower the amount of exiting radiation. The radiation absorption is a function of the amount of liquid, froth, and metal present between the column walls in the area being scanned.

A gamma ray source and radiation detector are lowered simultaneously along opposite sides of a distillation column. The intensity is recorded at predetermined length intervals or positions along the side of the column. A radiation absorption profile is then produced. Tray structures and deck liquid provide the highest radiation absorption. Vapor spaces provide the lowest absorption. Froths and foams appear between these two boundary conditions, depending on their densities and heights.

When scanning conventional crossflow trays, the gamma scan is conducted in a straight line across either the tray deck or the downcomer in order to gain a tray deck or downcomer profile, respectively. Ideally, these scans are only affected by the density of the tray ring and process conditions on the tray or in the downcomer.

The gamma scanning of columns containing closely spaced MD trays presents an interpretive challenge to the gamma scanning company and to their client. By design, the downcomers of MD trays extend into the vapor space of the tray below. Even if the trays are operating under normal design conditions and not near flood, the gamma scan could erroneously report this tray as flooded due to the amount of radiation absorbed by the downcomers.

EXAMINATION

To gain a better understanding of gamma scanning columns containing closely spaced MD trays, UOP requested Synetix's assistance to perform a Tracerco diagnostic scan. Several scans were completed utilizing the UOP 2,438-mm diameter column test apparatus located in Tonawanda, New York, U.S.A.. This apparatus is presented in Figure 1. The column was operated with an air-water system. Figure 2 depicts a typical MD tray. For this examination, three, two-downcomer UOP Enhanced Capacity Multiple Downcomer (ECMD) trays equipped with Anti-Penetration Pans (APP's) and Castellated Disengagement Plates (CDP's) were scanned.

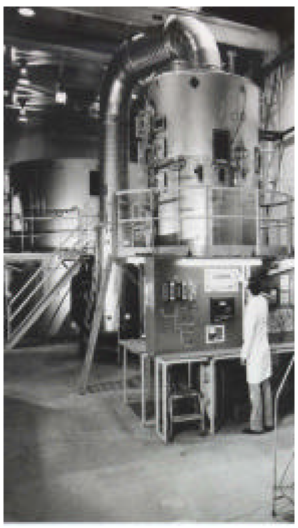


Figure 1: UOP Test Apparatus

Figure 2: UOP MD Tray

Figure 3 presents three scan lines utilized during this examination. The column was run under several conditions to include dry, weeping, design, turnup, downcomer blowby, and flood operation. Gamma scanning was completed for all these runs. Scale drawings of the column internals were placed side-by-side with the scans for accurate comparisons.

Figure 4 presents the dry operation profile of the trays utilizing Scan Line 1. Intensity spikes are located at each tray location. Note the intensity plateau associated with the presence of the castellated disengagement plates (CDP) located above the middle tray. Also note the intensity shoulder corresponding to the presence of the middle tray downcomers (DC). Also note the increase in absorption located just above the bottom tray location. This indicates the presence of the anti-penetration pans (APP).

Figure 5 presents the dry operation profile of the trays utilizing Scan Line 2 (rotated 90° from Scan Line 1). Intensity spikes appear at each tray location. Note the intensity plateaus of the CDP's located above the top and bottom trays. Also note the intensity shoulder corresponding to the downcomers of the top and bottom trays. Also note the increase in absorption located just above the middle tray location. This indicates the presence of the APP's.

Figure 6 presents dry, flood, and two turnup operation profiles (one just above design and the other just below flood conditions) of the trays utilizing Scan Line 1. Note how the vapor space above each tray, especially above the top tray, begins to show more absorption as the froth becomes higher and higher.

The height of the froth cannot be accurately determined because the absorption is not completely accurate. Assumptions must be made to determine which densities indicate froth, spray, and clear liquid on the tray deck. These assumptions may differ from one customer and/or field service consultant to another. Furthermore, gamma radiation does not propagate as a perfect collimated beam. It does tend to scatter, producing "fuzzy" pictures of the froth/liquid heights. The overlapping of responses from liquid exiting the downcomer, the tray froth, and the mechanical tray aspects also make predicting exact froth heights difficult.

Note the constant presence of the downcomer intensity shoulder from the middle tray. To those unfamiliar with interpreting gamma scans of MD trays, a conclusion of tray flood may be reached far before actual flood due to the apparent increase in density caused by the presence of the downcomers in the vapor space of the tray below.

Figure 7 represents dry, design, blowby, fluidization, and weeping operation profiles of the trays utilizing Scan Line 2. Please note that the blowby, fluidization, and weeping operations are relatively indistinguishable. Note the downcomer intensity shoulders from the top and bottom trays.

Figure 8 presents a gamma scan profile of the downcomers (Scan Line 3) under dry conditions. Note the progression of the intensity areas and spikes. The first tray-related intensity area (plateau) is associated with the CDP. After the top tray spike, the next represents the bottom of the downcomers. The following spike represents the presence of the CDP attachment hardware. The next spike is the middle tray. The next large absorption represents the presence of the CDP's of the bottom tray. The next intensity increase corresponds to the presence of the APP's followed by the outlet weirs of the bottom tray, the bottom tray itself, and the bottom tray downcomers.

Figure 9 presents a gamma scan profile of the downcomers (Scan Line 3) under dry and design conditions. Again, note the progression of the intensity spikes as addressed in Figure 8. Further, note that the vapor spaces (intensity valleys of the dry line) are now showing a higher intensity profile, showing us that the liquid / froth is present in the downcomers. The exact amount of liquid and/or the exact liquid level cannot be inarguably determined due to radiation scatter and the overlapping of the downcomer liquid and the downcomer box responses.

Note especially here that with the dry scan baseline, we are able to determine that large portions of the intensity areas under design conditions are due to tray hardware, not flooded conditions.

CONCLUSIONS

The following conclusions were reached following the analysis of the gamma scans of the UOP test column containing closely spaced MD trays:

A. Gamma scanning cannot be utilized with closely spaced MD trays to:

1. Detect deck weeping, fluidization, or downcomer blowby

2. Precisely determine froth height and the liquid level in downcomers and distributors due to the overlapping of hydraulic and mechanical responses inherent to the MD tray and radiation scatter

B. Gamma scanning can be utilized to:

1. Locate tray positions, tray damage, tray orientations, downcomers, weirs, anti-penetration pans, castellated disengagement plates, distributors, and horizontal and vertical feeds under wet or dry conditions, preferably under dry conditions

2. Identify the presence of froths on trays and of liquid in distributors and downcomers

3. Detect flooding and the onset thereof

RECOMMENDATIONS

The following recommendations were reached following the analysis of the gamma scans of the UOP test column containing closely spaced MD trays:

A. Effective gamma scanning is the result of:

1. Comparing operating data scans to that of a dry and normal operation baseline scans

2. Scanning with 25 mm increments when tray spacings are small

3. Utilizing 13 mm, 25 mm, or 51 mm crystals when scanning columns, and employing larger detection crystals when scanning large diameter columns

4. Comparing operating scans, visual observations, pressure drops, internal flow rates, and hydraulic simulations

5. Possessing drawings depicting the column internals and placing them side-by-side with the gamma scans

Figure 3: Scan Line Orientations of UOP Test Column

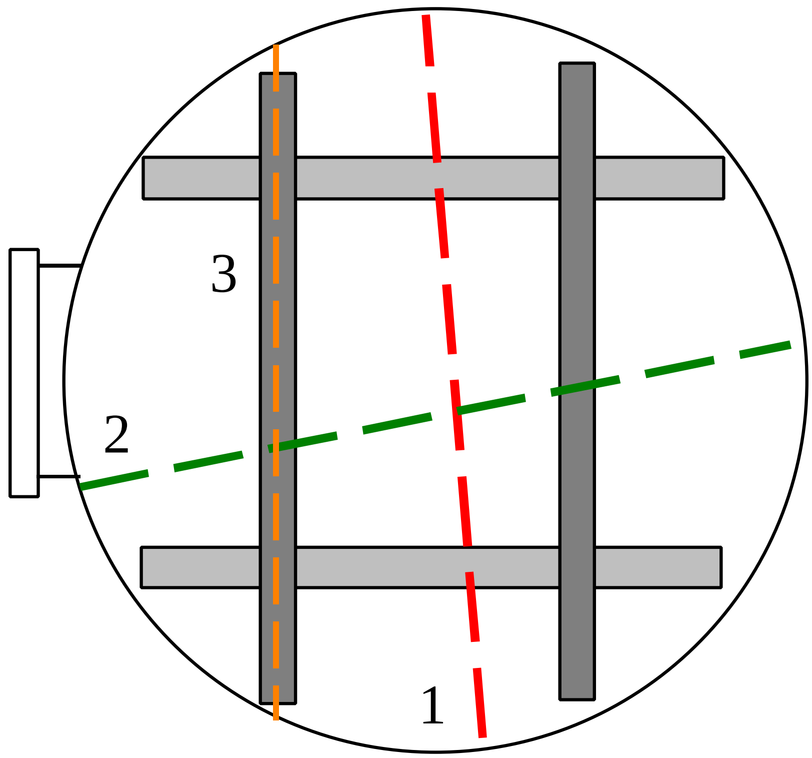


Figure 4: Scan Line 1 – UOP Test Column: Dry Scan

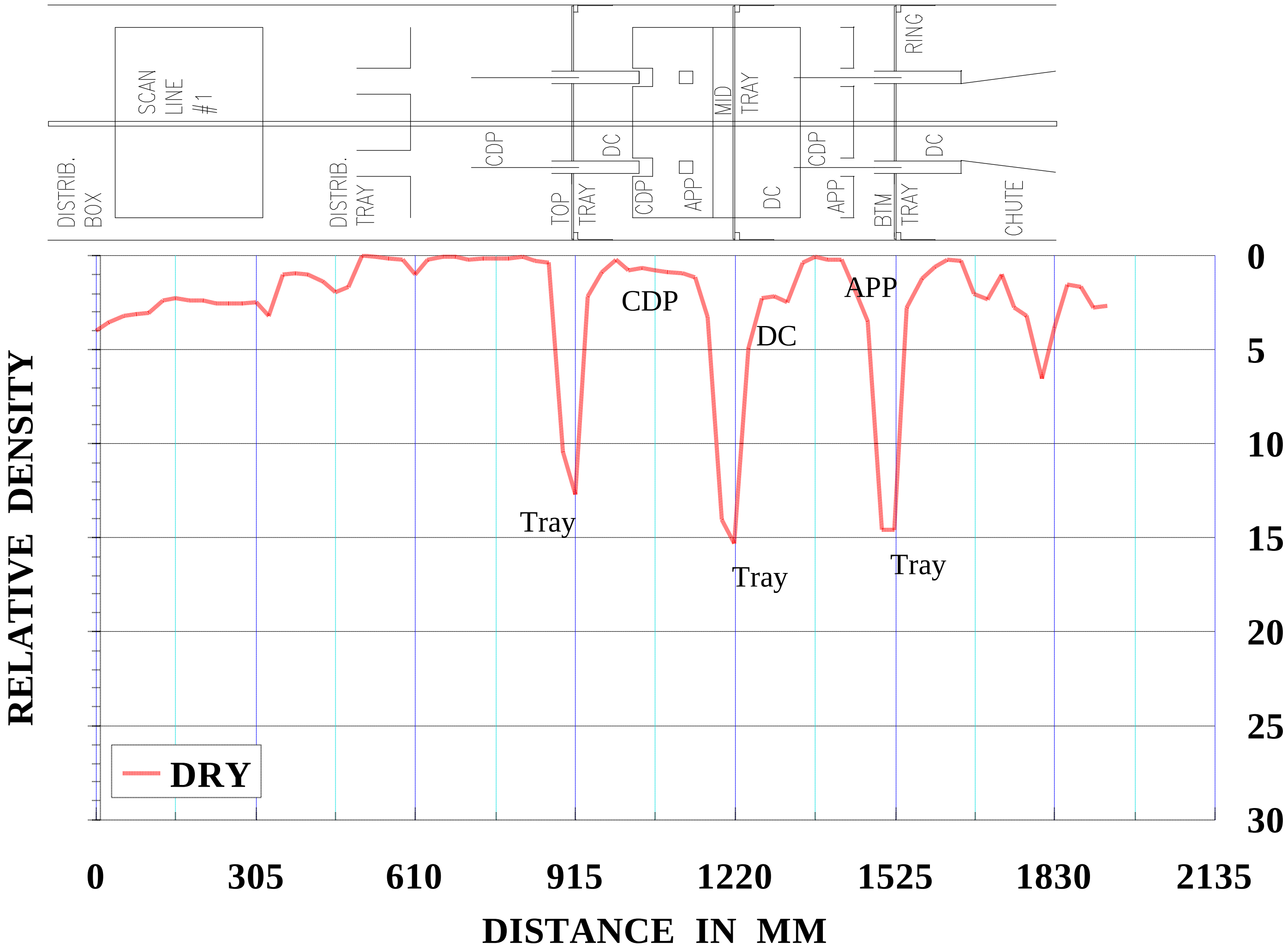


Figure 5: Scan Line 2 – UOP Test Column: Dry Scan

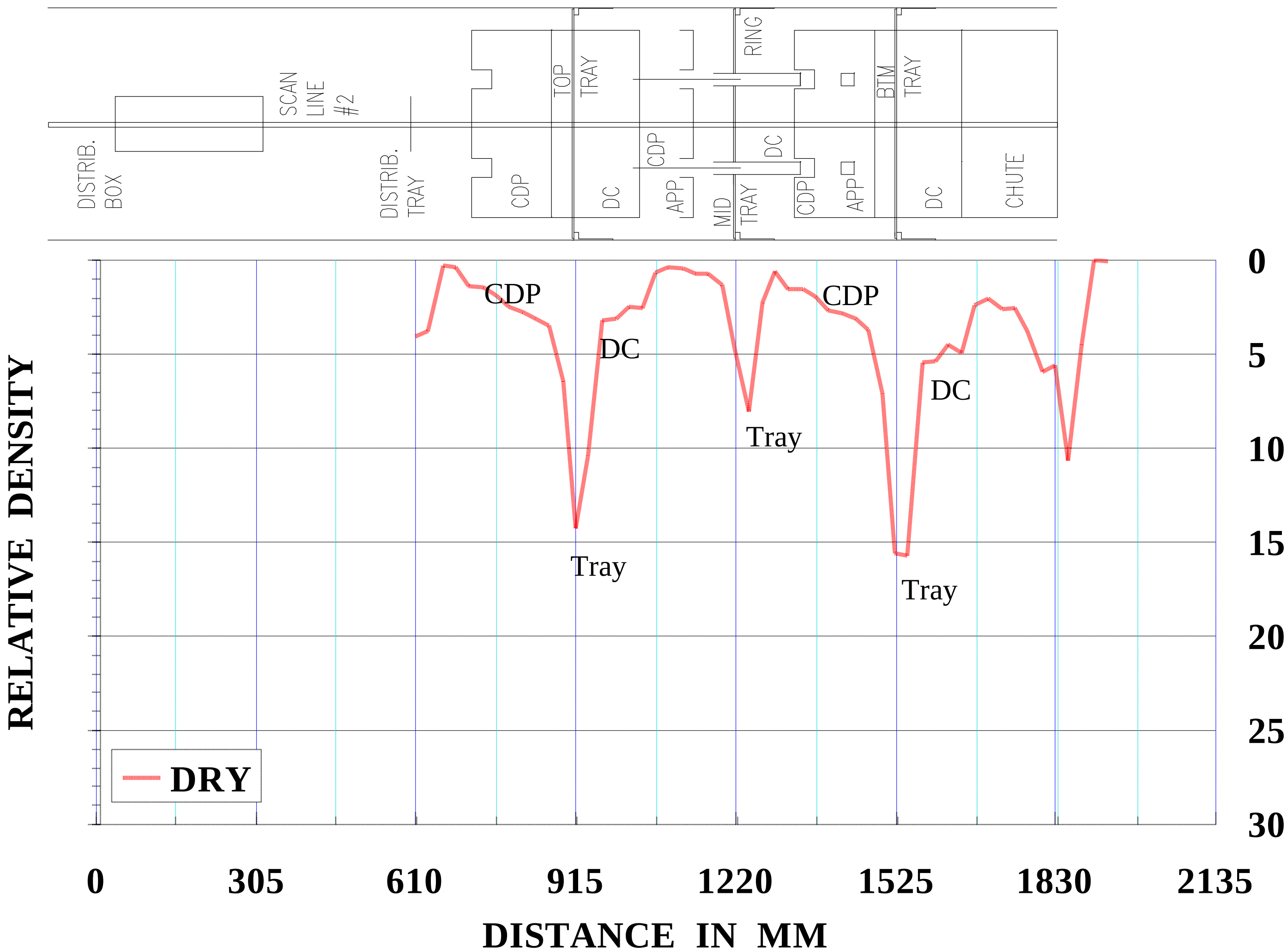
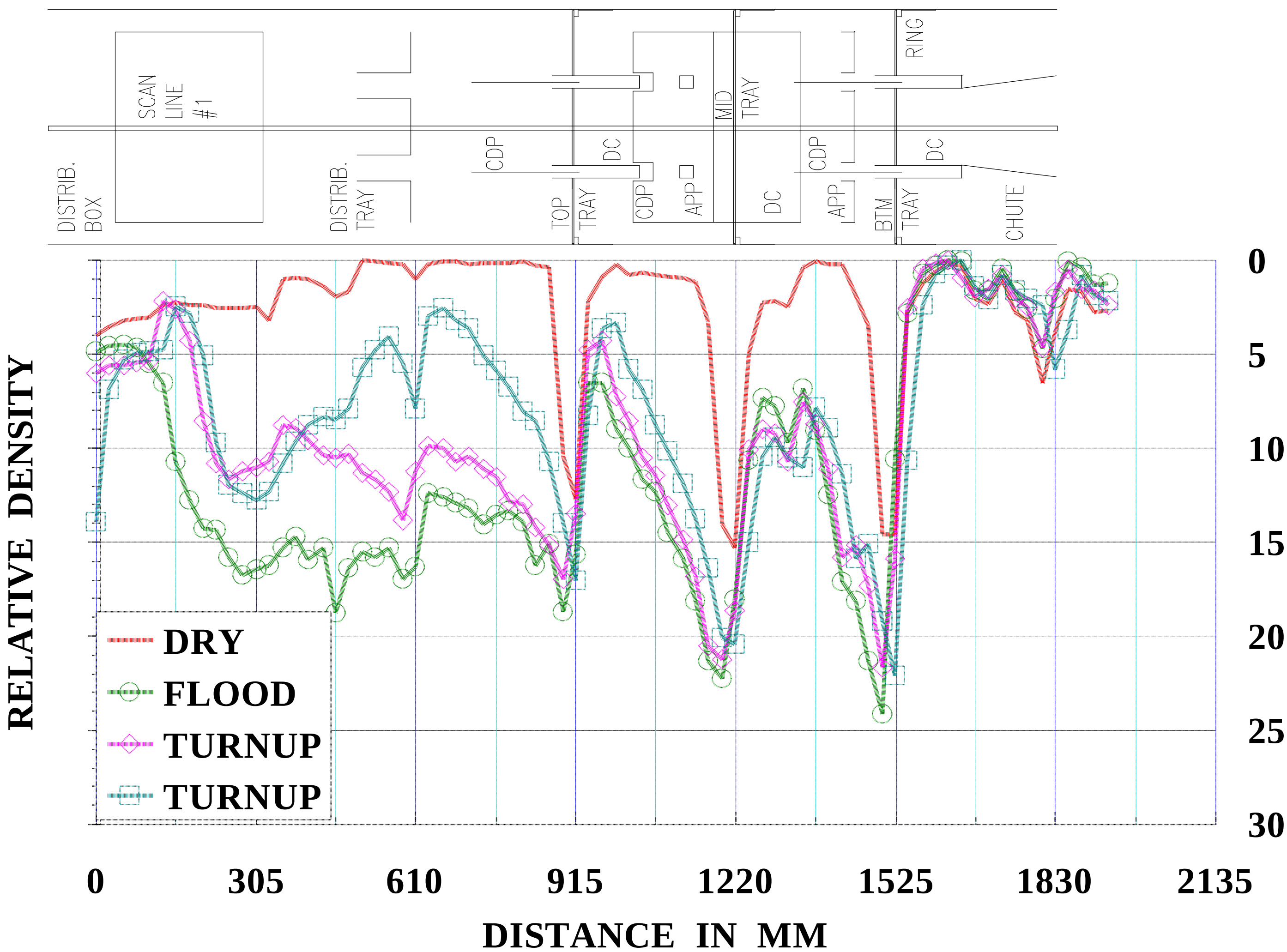


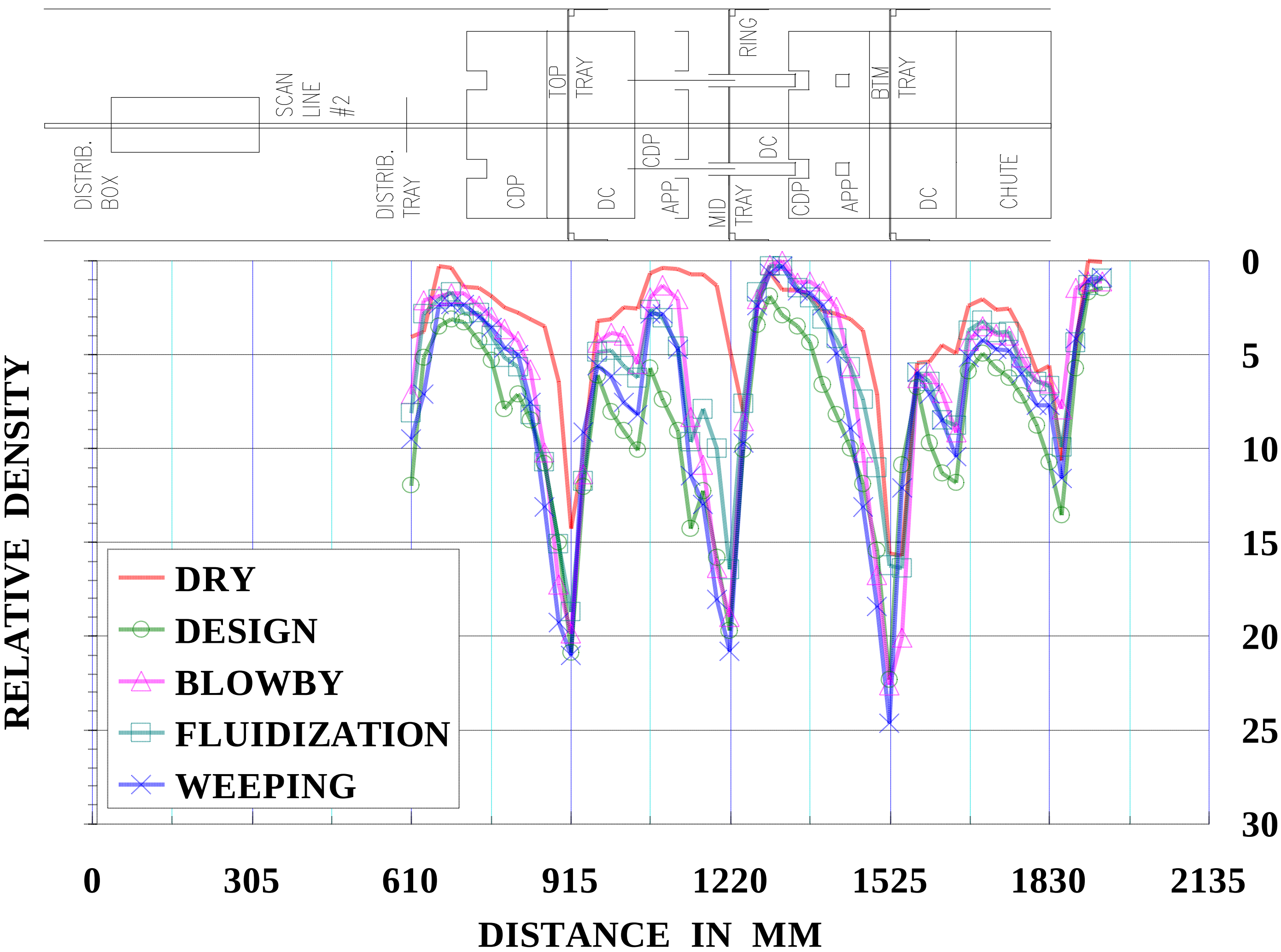
Figure 6: Scan Line 1 – UOP Test Column: Dry, Flood, and Two Turnup Scans



Note the increases in intensity profiles. These increases are due to the presence of froth on the tray deck.

Note the flooded conditions on the top tray. The intensities from the froth on the deck are almost as high as those associated with the trays.

Figure 7: Scan Line 2 – UOP Test Column: Dry, Design, Blowby, Fluidization, and Weeping Scans



Note the relative indifference between these conditions.

Figure 8: Scan Line 3 – UOP Test Column: Dry Scan

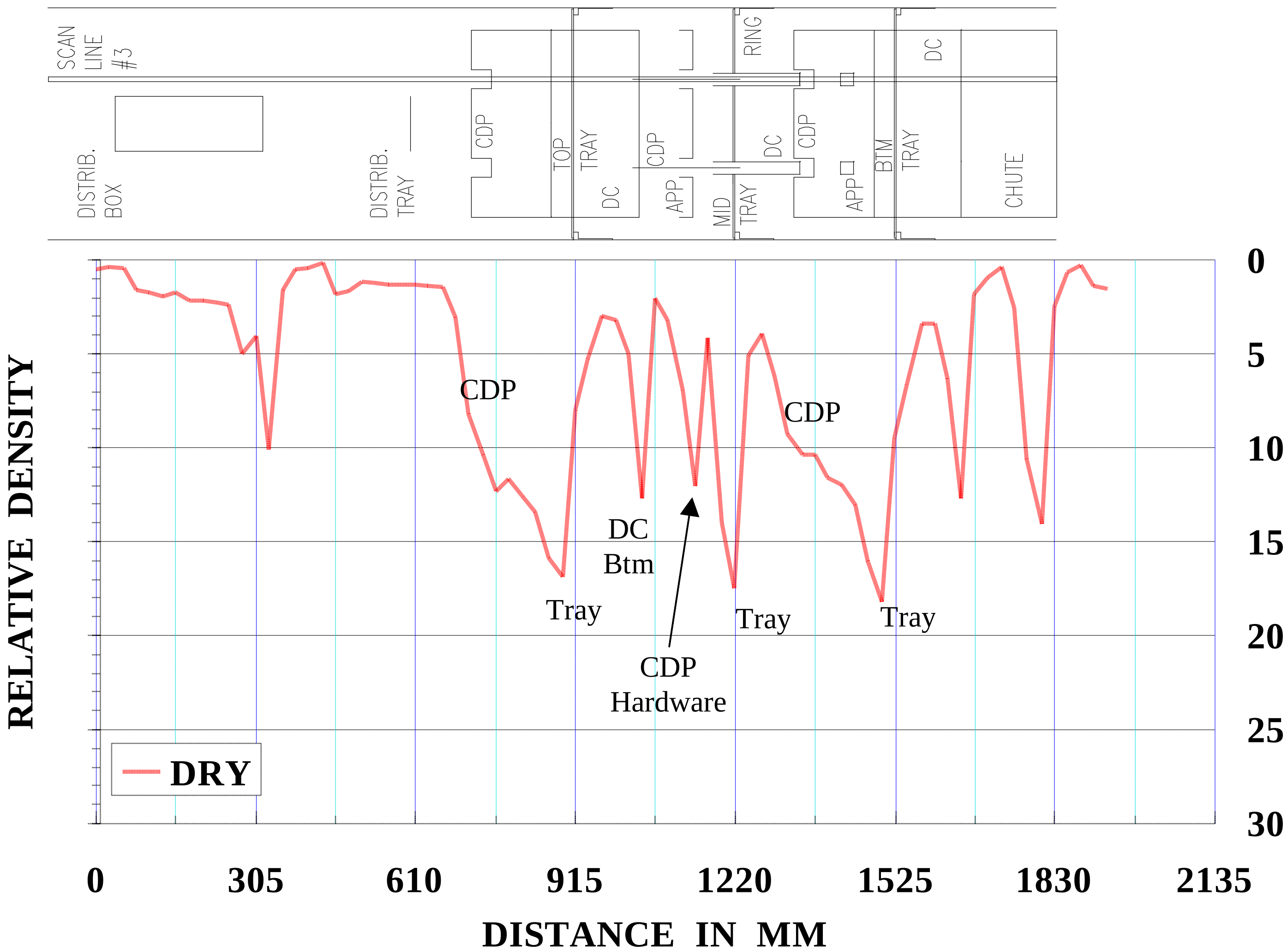
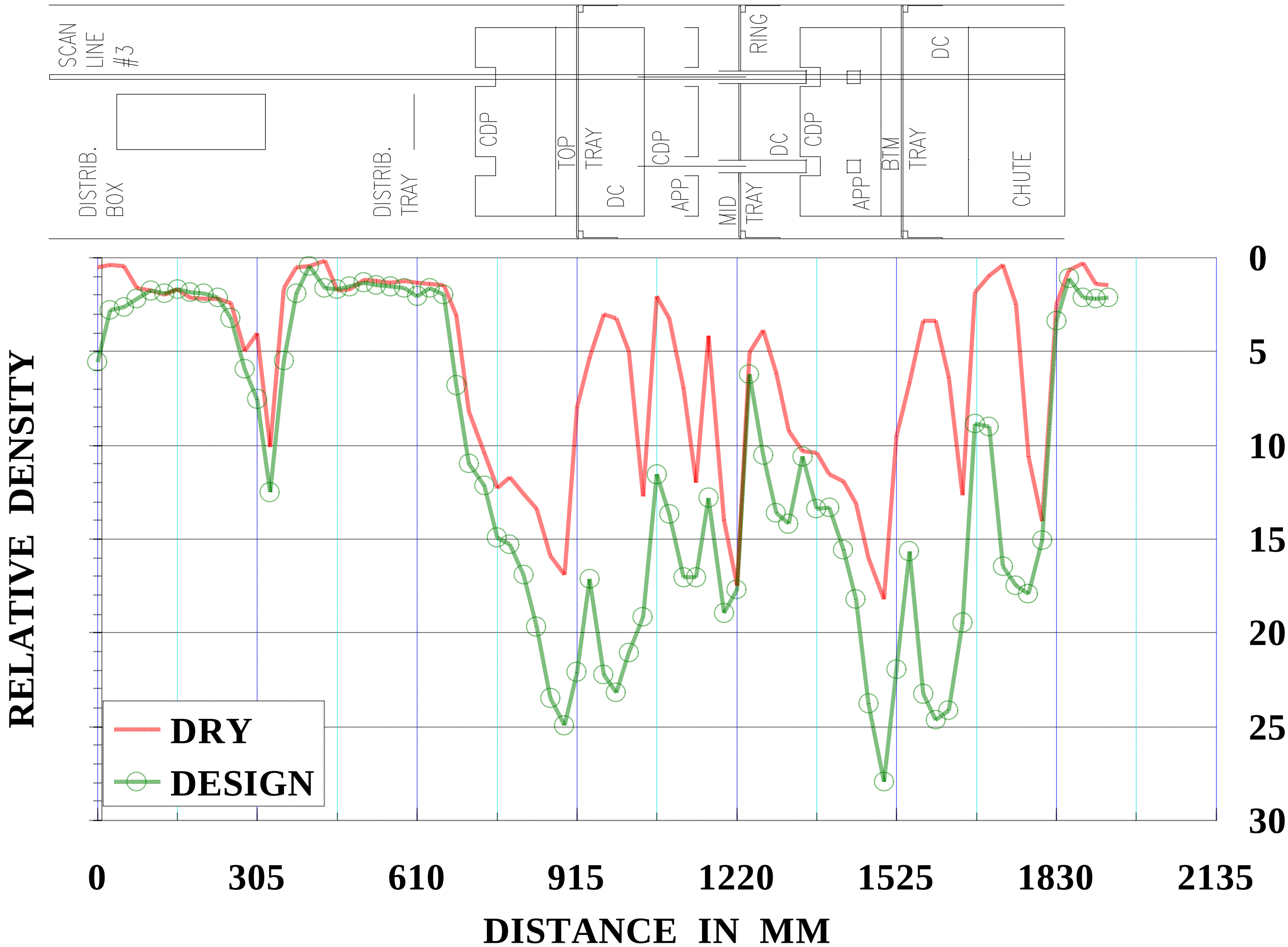


Figure 9: Scan Line 3 – UOP Test Column: Dry and Design Scans



Note the increases in the intensity profile. These increases are due to the presence of froth on the tray deck and liquid in the downcomers.

Note that with the dry scan baseline, we are able to determine that large portions of the intensity areas under design conditions are due to tray hardware, not flooded conditions.