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Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 40H

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REVIEWS AND APPROVALS

EXECUTIVE SUMMARY

The SRNL Atmospheric Technologies Group performed an analysis for mercury emissions from H-Tank Farm - Tank 40 ventilation system exhaust in order to assess whether the Short Term Exposure Limit (STEL), or Threshold Limit Value (TLV) levels for mercury will be exceeded during bulk sludge slurry mixing and sludge removal operations. The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was used as the main dispersion modelling tool for this analysis.

The results indicated that a 45-foot stack is sufficient to raise the plume centerline from the Tank 40 release to prevent mercury exposure problems for any of the stack discharge scenarios provided. However, a 42-foot stack at Tank 40 is sufficient to prevent mercury exposure concerns in all emission scenarios except the 50 mg/m^3 release. At a 42-foot stack height, values exceeding the exposure standards are only measured on receptors located above 34 feet.

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AMS	American Meteorological Society
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AERMET	AERMOD Meteorological Preprocessor
AGL	Above Ground Level
ASL	Above Sea Level
ATG	Atmospheric Technologies Group
BPIP-Prime	Building Profile Input Program- Prime Algorithm
DSA	Documented Safety Analysis
EPA	Environmental Protection Agency
LIDAR	Light Detection and Ranging
NWS	National Weather Service
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
USGS	United States Geological Survey

1.0 Introduction

The American Conference of Governmental Industrial Hygienists (ACGIH) short term exposure limit (STEL) for dimethyl mercury and 8–hour threshold limit value (TLV) for mercury in the workplace are 0.030 mg/m^3 (30 µg/m^3) and 0.025 mg/m^3 (25 µg/m^3), respectively (Refs. 1 and 15). Using these standards, the Atmospheric Technologies Group (ATG) has been asked to evaluate the exposure of workers to mercury concentrations resulting from the H-area tank farm Tank 40 purge ventilation stack emissions. The STEL for dimethyl mercury was used because a STEL for elemental mercury has not been reported by the ACGIH ambient concentrations standard. Mercury concentrations were predicted for ground-level breathing height and other specific work areas around Tank 40.

In order to predict the mercury concentrations for Tank 40, observed weather data was taken from a five-year (2007-2011) record of hourly meteorological conditions and used to calculate the amount of atmospheric dispersion for 1-hour and 8-hour time periods. Hourly-averaged modeled concentrations were adjusted to represent 15-minute values for comparison to the 15-minute STEL using the following equation (Ref. 3):

$$\boldsymbol{C_{15min} = C_{60min}\left(\frac{60}{15}\right)^{0.2} = 1.3\ C_{60min}} \qquad (1)$$

By multiplying the hourly concentrations by a factor of 1.3, the concentration is representative of concentrations sampled on a 15-minute time averaged period. Comparisons of the calculated concentrations can be made to the standards, and estimates of worker safety and potential mitigations methods can easily be made.

2.0 Methodology

Modeling was conducted with the Environmental Protection Agency (EPA) AMS/EPA Regulatory Model (AERMOD) dispersion model, which is recommended by the EPA for regulatory air quality analyses (Ref. 4). The model allows for variability in wind, turbulence, temperature and incorporated boundary layer parameters for dispersion through the boundary layer in both stable and convective atmospheric situations (Refs. 5 and 6). More information on ATG's software quality assurance plan for AERMOD can be found in document number C-SQP-G-00076 (Ref. 7). For this regulatory modeling, AERMOD was executed in default (regulatory) mode. AERMOD is routinely used for tank and multiple stack emissions, and has physics included to model building wake effects.

Meteorological data files used as input to AERMOD were prepared using EPA's AERMOD Meteorological preprocessor (AERMET, Ref. 9), which incorporates the National Weather Service's (NWS) hourly observations from Bush Field in Augusta, GA, twice-daily upper air soundings from the NWS Atlanta, GA radiosonde station and, quality assured 15-minute values of wind and temperature at four levels (4, 18, 36 and 61 meters) of the Savannah River Site (SRS) Central Climatology tower located near N-area.

For onsite data, values were extracted from the meteorological database and written to a text file only if there were no associated quality flags. When the data did not meet quality control criteria, a missing value code was assigned consistent with AERMET requirements. Quality assurance procedures for SRS meteorological data are described in Reference 10. For details on the processing of the most recent five year quality assured dataset (2007-2011) see References 11 and 12.

Values used by AERMET for roughness length, Bowen ratio and albedo were determined from EPA's AERSURFACE algorithm. Input to the algorithm consisted of a (United States Geological Survey) USGS National Land Cover Data image for 1992 (NLCD92). This image was analyzed for the area around the Central Climatology tower. Monthly values of the three surface parameters were generated and imported into AERMET.

Building information was included in AERMOD to account for downwash and re-circulation effects from buildings and stacks. Building data was processed using the EPA utility Building Profile Input Program (BPIP-Prime) to determine how these obstacles affect airflow patterns and the transport of effluent discharge. Of particular concern is the downwash of the plume around the areas where workers will spend most of their time during operations. The structures included in the Tank 40 model domain for the BPIP-Prime input are the two platforms on top of Tank 40, the 16H Evaporator Building, and buildings 241-28H and 241-82H (Figure 2-1 and 2-2). Additionally, buildings to the south of Tank 40 were also included the modelling domain. The building heights used were obtained from building drawings (Refs. 16-19) and combined with a model domain created for previous assessments of the area documented on Refs. 13 and 14.

There are numerous small appurtenances in the vicinity of Tank 40; however these were not modeled for atmospheric wake, adding a level of conservatism (wake area adds additional turbulence for dispersion which can lower atmospheric concentrations). The larger buildings need to be retained, in order for AERMOD to enhance the vertical mixing of the plume centerline down to the receptor heights, increasing the near surface ground concentrations. The tank itself was given a height of 0.10 meters (about 4 inches). BPIP-Prime was re-run for every change in stack height in order to determine the impact of the downwash from each wake on the stack, as well as the revised stack tip downwash component.

Terrain elevation was determined from the Savannah River Site (SRS) high resolution Light Detection and Ranging (LIDAR) dataset for SRS (Refs. 2 and 8). The area surrounding Tank 40 is on the top of a hill that has been graded to be approximately 100 to 101 meters (m) above sea level (ASL, Fig. 2-1).

The modeling domain was defined with a receptor grid of 51 by 41 (2091 receptors), with ground level receptors placed every 5 m to identify any potential excessive concentrations that may occur near the ground. Hence, the height of these receptors is nominally 1.83 m (6 feet, Ref. 1), which represents the breathing zone of a tall worker standing at ground level. Additionally, several flagpole receptors were placed to represent elevated locations of interest (Ref. 1). A single receptor was placed at the middle of the Tank 40 at a height of 4.88m (10 feet platform plus 6 feet breathing zone above the tank, Ref. 1). Eight receptors where placed above the top of the 16H Evaporator Platform breathing zone (6 receptors at a total elevation of 24.17 ft and 2 receptors at the max elevation of 38.58, Ref. 1). Elevated receptors were also were placed at building 242-82H at 22 ft and at the building max height of 34 ft. Additionally, 23 individual receptors were placed along the edge of the platforms, generally at the 4 corners and the center of the structure. Each of these platform receptors was repeated so that the platform levels of 5, 10 and 15 feet (plus 6 feet for the breathing level), giving receptor heights of 11, 16 and 21 feet (3.35, 4.88 and 6.40 m, Ref. 1) above ground level (AGL), could be represented as described in Reference 1. The coordinate system used was a custom UTM grid, using the NAD27 datum. An adjustment of -36^o was made to the wind direction to align the SRS coordinate system to True North.

The operating characteristics of the stack/source are defined by the following parameters, and are listed in Reference 1. During operations, Tank 40 exhibits a purge exhaust flow rate of 346 cubic feet per minute (cfm). The stack discharge temperature is estimated to be 65°C (149^{o}F) and the inside diameter of the stack is 6.407 inches (in, Ref. 1). The current stack height is approximately 20 feet (ft, Ref. 1). For the purpose of this analysis the value of stack height was adjusted to various heights to determine the minimum stack height at which the mercury concentrations around the stack are below the various exposure limits.

The concentration of mercury in the stack discharge was converted to a mass release by using the flow rate for the stack in order to have the correct units for input on AERMOD. The emission rate for the Tank 40 stack (in g/s) was determined using the following calculation based on inputs from Reference 1:

$$\frac{10\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{346\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.001634\text{ g/s}$$

$$\frac{25\text{ mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{346\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.004085\text{ g/s}$$

$$\frac{50\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{346\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.008171\text{ g/s}$$

Finally, once mercury concentration values were calculated for each receptor on the grid, values were transformed to percent of corresponding standard. This was done by multiplying each value by a scaling factor of 4.3 and 4.0, for the 15-minute and 8-hour period, respectively. These scaling factors were obtained using the following calculation:

$$\%\text{ of STEL} = \frac{1.3}{30\ \mu g/m^3} \times 100 = 4.3$$

$$\%\text{ of TVL} = \frac{1}{25\ \mu g/m^3} \times 100 = 4.0$$

where the value 1.3 in the first equation is incorporated from Eq. 1 in order to obtain values representative of a 15-minute time period.

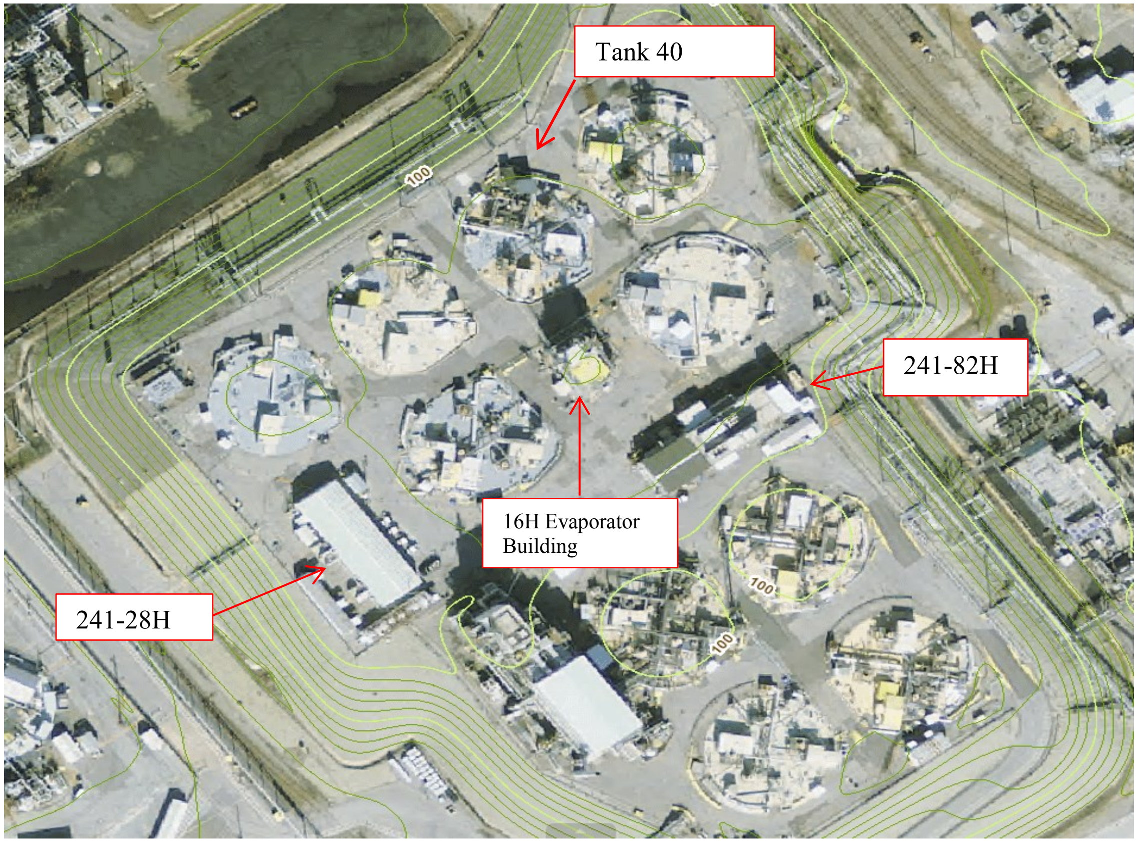

Figure 2-1. Aerial photo of H-Tank farm, with LIDAR elevations (light green contours) around Tank 40 (Ref. 2).

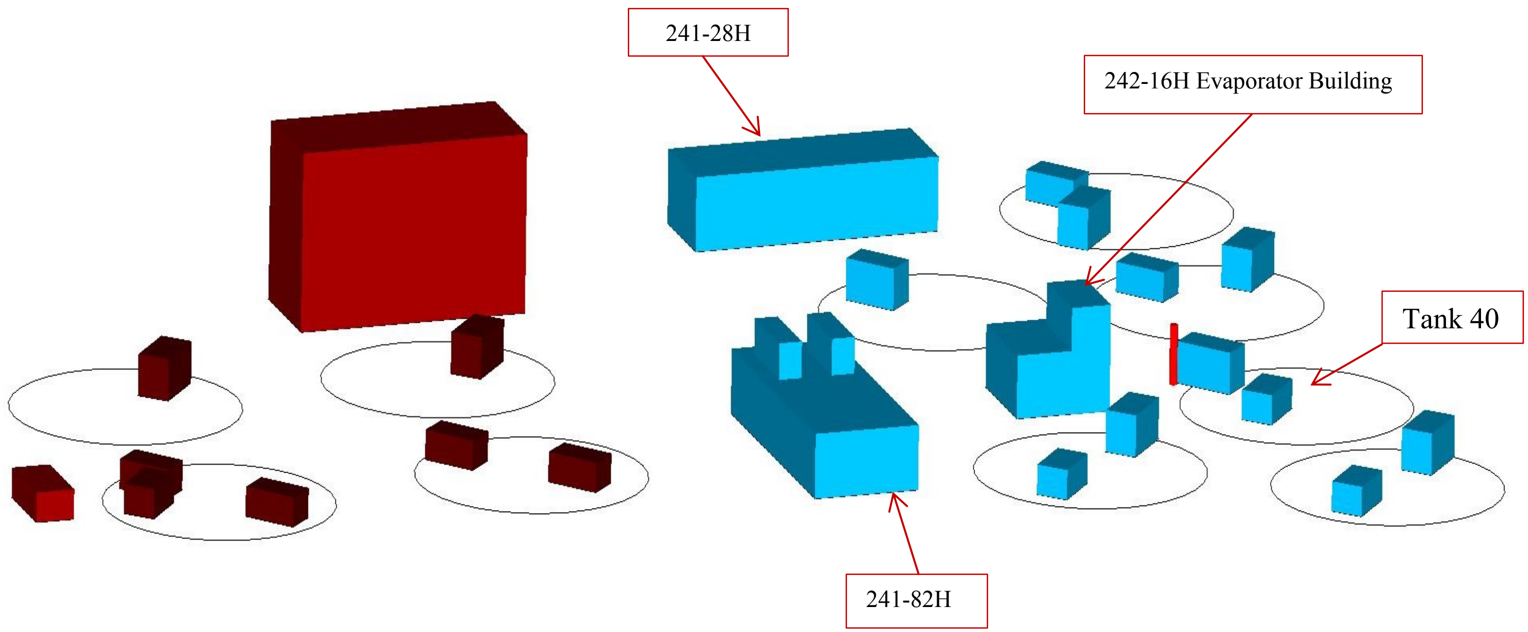

Figure 2-2. Three dimensional view of the buildings around Tank 40 for the 20-foot stack height from AERMOD modeling domain. The buildings near Tank 40 are colored in blue, tanks are represented by circles, and the stack is in red. Buildings on the south side of the hill are colored in maroon. View is from the East, looking West.

3.0 Results and Discussion

Modeling was conducted based on the release characteristics previously summarized in order to assess compliance of the 15-minute STEL for dimethyl mercury (0.030 mg/m^3 or 30 $\mu g/m^3$) and 8-hour TLV for mercury (0.025 mg/m^3 or 25 $\mu g/m^3$) given in Reference 1. AERMOD was set to output 1-hour and 8-hour time weighted averages, and the 1-hour values were adjusted to a 15-minute averaging period. The inputs were kept constant except for stack height and stack discharge. The stack height was initially set to 20 ft, and then increased incrementally until the concentration on all receptor locations were below the standard value for the respective time weighted average. The stack discharge was set to 10 mg/m^3, and then increased to 25 mg/m^3 and 50 mg/m^3 (Ref. 1).

Table 3-1 summarizes the results from the runs, with Figures 3-1 to 3-8 highlighting the receptor locations exceeding the concentration standards. Values at each receptor are expressed as a percent of the standard. Only the values that exceed 100% are shown in each figure, i.e. values that are exceeding the standard (STEL or TVL, respectively). Figures are not presented for scenarios that did not have exceedances.

3.1 Stack Discharge of 10 mg/m^3

For a 20-ft stack, both of the mercury concentration standards are exceeded on a 10 mg/m^3 stack discharge scenario (Table 3-1). The receptors with values exceeding the 15-minute STEL exposure limit are located around the walking platforms and various ground level areas around the stack (Figure 3-1). The exceedance at elevated receptors is large because the plume centerline is close to these receptors. Similarly, the 8-hr TLV is exceeded but only on one receptor located directly south of the stack (Figure 3-2). This was the lowest value of stack discharge of the 3 scenarios used for this study (Ref. 1). Hence, results for additional emissions scenarios are not presented for the 20-ft stack since they would have produced concentrations larger than the 10 mg/m^3 scenario, which already exceed both standards.

A 30-ft stack height was found sufficient to obtain concentrations values that were well below exposure limits for the 8-hour period. However, at this stack height was not sufficient to comply with STEL for 10 mg/m^3 discharge scenario. Additionally, this height was found not sufficient to comply with standards on the remaining two stack discharge scenarios provided (Table 3-1).

A 40-ft stack proved sufficient to comply with both exposure limits given a stack discharge of 10 mg/m^3.

3.2 Stack Discharge of 25 mg/m^3

When a 30-ft stack was modeled, the STEL value was exceeded for the 25 mg/m^3 discharge scenario, while TVL value was not exceeded for this scenario (Table 3-1). Receptors with concentration values exceeding STEL for the 15-minute period are located over an elevated platform on the northern section of Tank 40 and at the maximum heights of the 242-16H and 241-82H buildings (Figure 3-4).

Raising the stack height to 40 ft proved sufficient to comply with both exposure limits for this stack discharge scenario. In contrast, if stack discharge is increased (see section 3.2), this level would still result in exceedance of the 15-minute exposure limits on some locations around the tank, as discussed below.

3.2 Stack Discharge of 50 mg/m³

For this discharge scenario a higher 45-ft stack was needed in order to comply with both exposure limits. For a 30-ft stack height, both exposure limits were exceeded (Table 3-1, Figures 3-5 and 3-6). Similarly, the 40-ft stack height and the 42-ft stack height exhibited exceedances of the STEL standard at the 50 mg/m^3 stack discharge scenario (Table 3-1, Figure 3-7 and 3-8). No exceedances were predicted for either of these two stack heights (40-ft and 42-ft stack heights) for an 8 hour averaging period (TVL). It is important to note that the exceedances of STEL at the 40-ft and 42-ft stack heights are limited to receptors located above 34 ft on building 242-16H and 242-82H (Figure 3-7 and 3-8). Additionally, exceedances at 42 ft are relatively small at these receptors. However, an additional run was made for a 45-ft stack height. At this height, no exceedances of the STEL or TLV were predicted for the 10 mg/m^3, 25 mg/m^3 or 50 mg/m^3 scenarios.

4.0 Conclusions

The focus of this report was to assess whether the applicable workplaces exposure standards for mercury will be exceeded during bulk sludge slurry mixing and sludge removal operations at the base stack height of 20 ft at Tank 40H. Additionally, an assessment of the stack height required to maintain concentrations below standards at various receptors is presented.

Results show that the minimum stack height to ensure concentrations below 15-min and 8-hr concentration standards (STEL and TVL, respectively) is 45 ft. This stack height provided concentration values below the standards for all stack discharge scenarios evaluated. At a lower heights (40 ft and 42 ft), most receptors showed concentration values below the standard limits, except at the 50 mg/m^3 scenario. For this scenario receptors located at heights above 34 ft show values above STEL (30 $\mu g/m^3$).

Table 3-1. Maximum ambient concentrations ($\mu g/m^3$) associated to Tank 40H emissions for 15-minute and 8-hour time period for all receptors.

Averaging Time	Tank 40 Stack Discharge	Tank 40 Stack Height				
		20-ft	***30-ft***	***40-ft***	***42 -ft***	***45- ft***
15-min	**10 mg/m³**	**130.02**	**63.76**	8.72	6.32	5.03
8-hour		**28.53**	6.25	4.72	3.17	2.56
15-min	**25 mg/m³**	Not included- values exceed standard at lower emission rate	**159.40**	21.80	15.81	12.56
8-hour			15.63	11.80	7.92	6.39
15-min	**50 mg/m³**		**318.84**	**43.61**	**31.62**	25.13
8-hour			**31.26**	23.59	15.85	12.79

Bolded values exceed exposure limits for respective time periods (0.030 mg/m^3 or 30 $\mu g/m^3$ for 15-min STEL and 0.025 mg/m^3 or 25 $\mu g/m^3$ for 8-hour TLV).

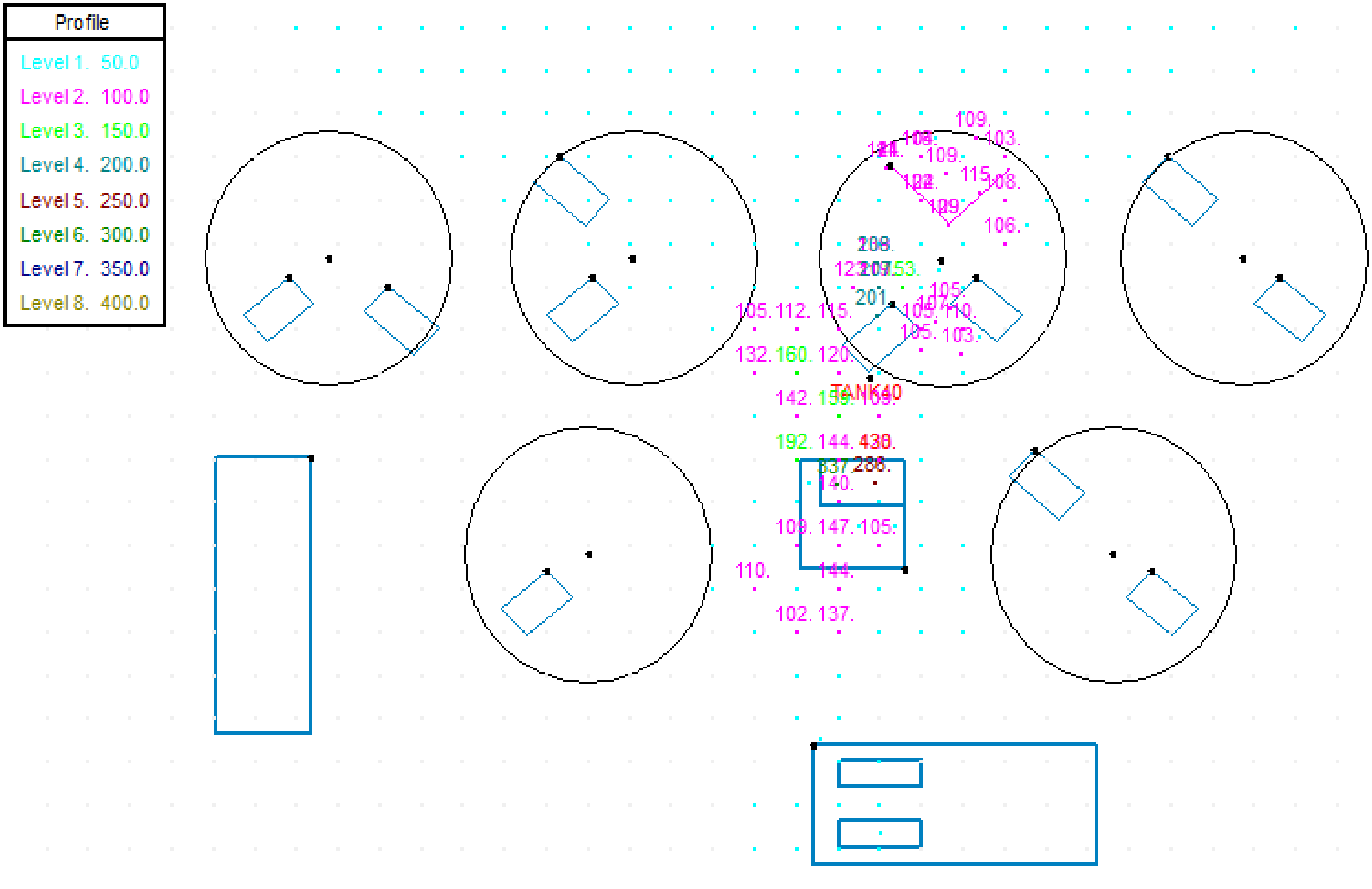

Figure 3-1. STEL Exceedances for Tank 40 with a 20-foot stack and 10 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

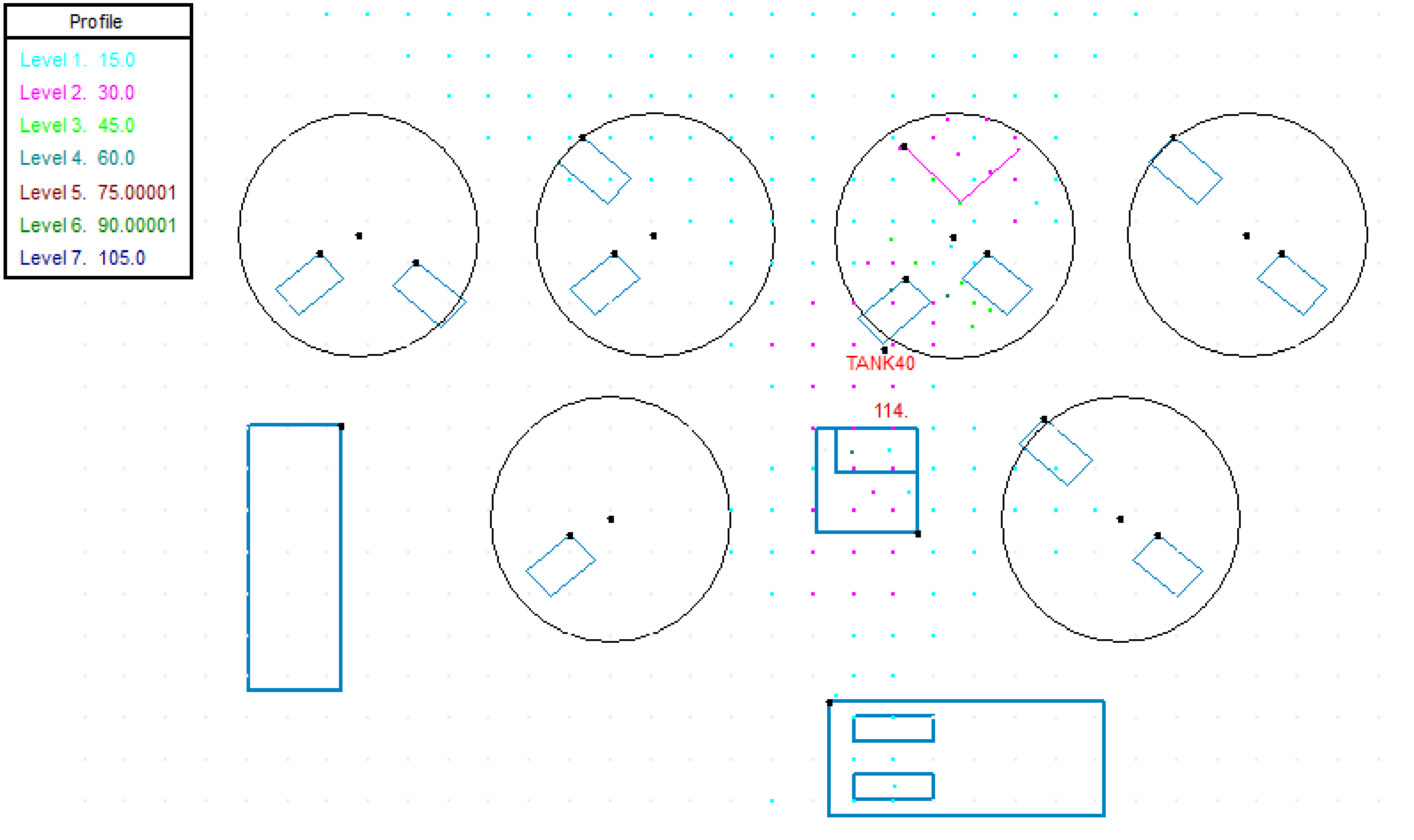

Figure 3-2. TLV Exceedances for Tank 40 with a 20-foot stack and 10 mg/m³ release concentration scenario. Values are expressed as a percentage of the TLV standard (25 µg/m³). Only values above 100% of the standard are displayed.

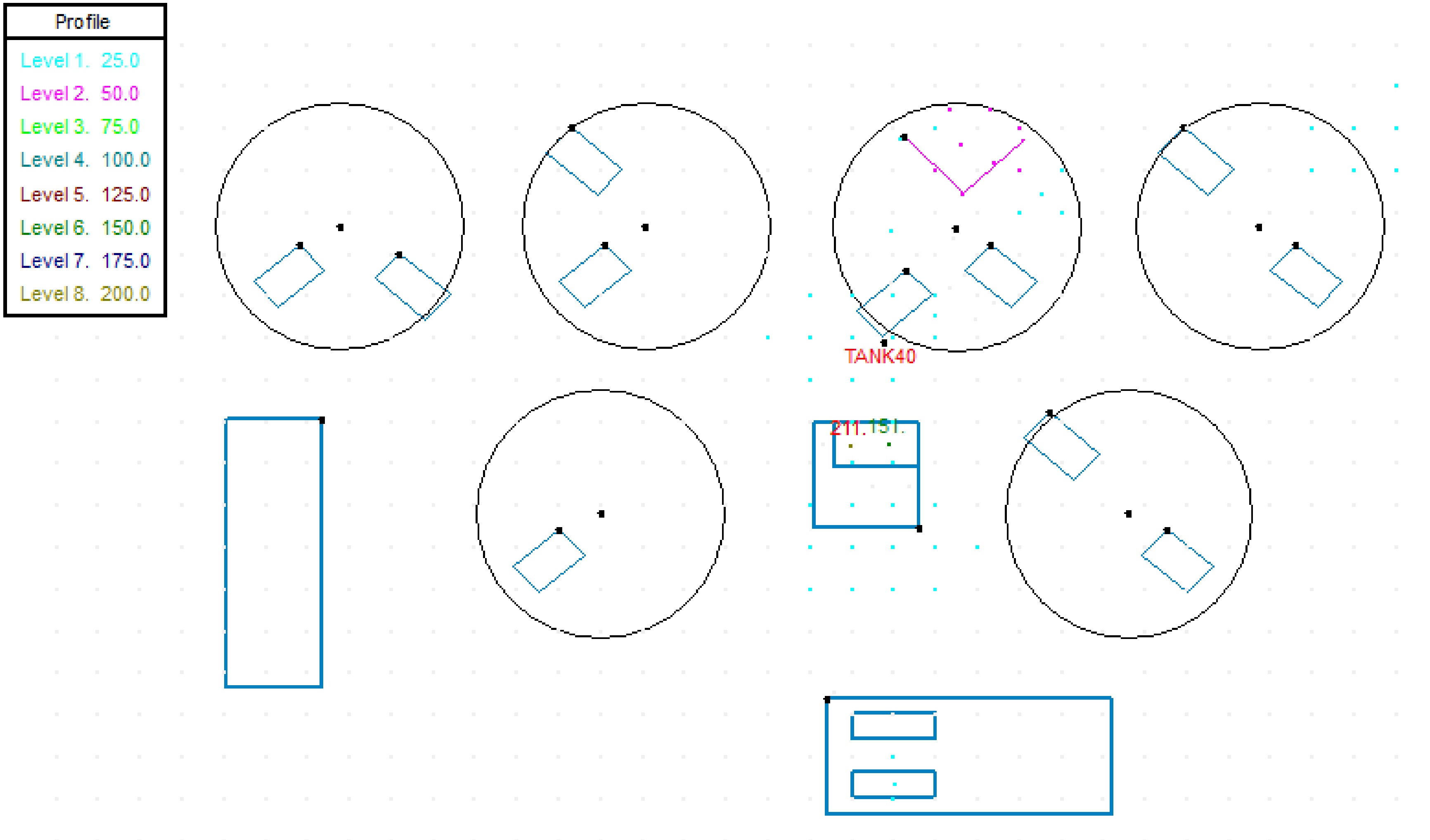

Figure 3-3. STEL Exceedances for Tank 40 with a 30-foot stack and 10 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

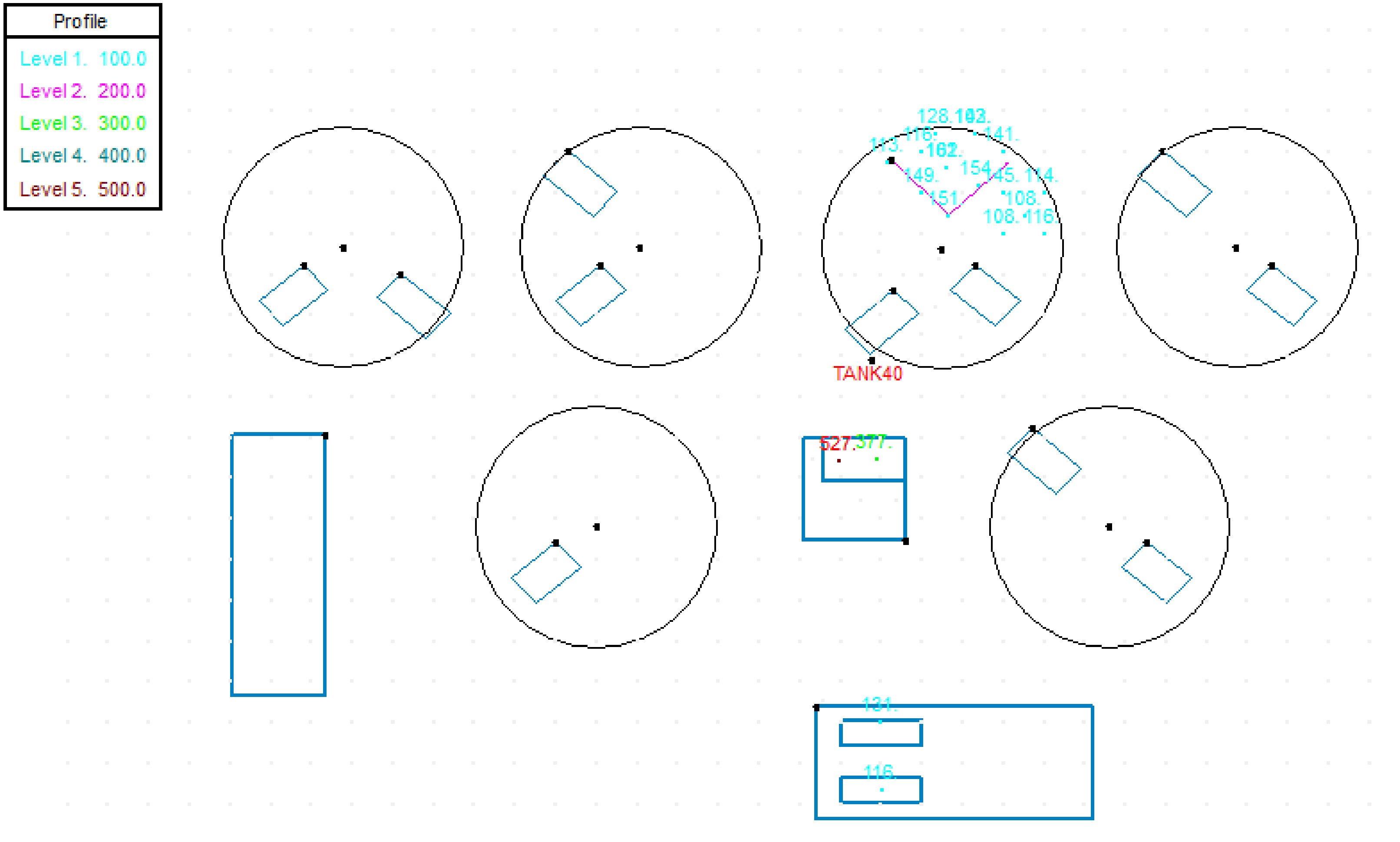

Figure 3-4. STEL Exceedances for Tank 40 with a 30-foot stack and 25 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

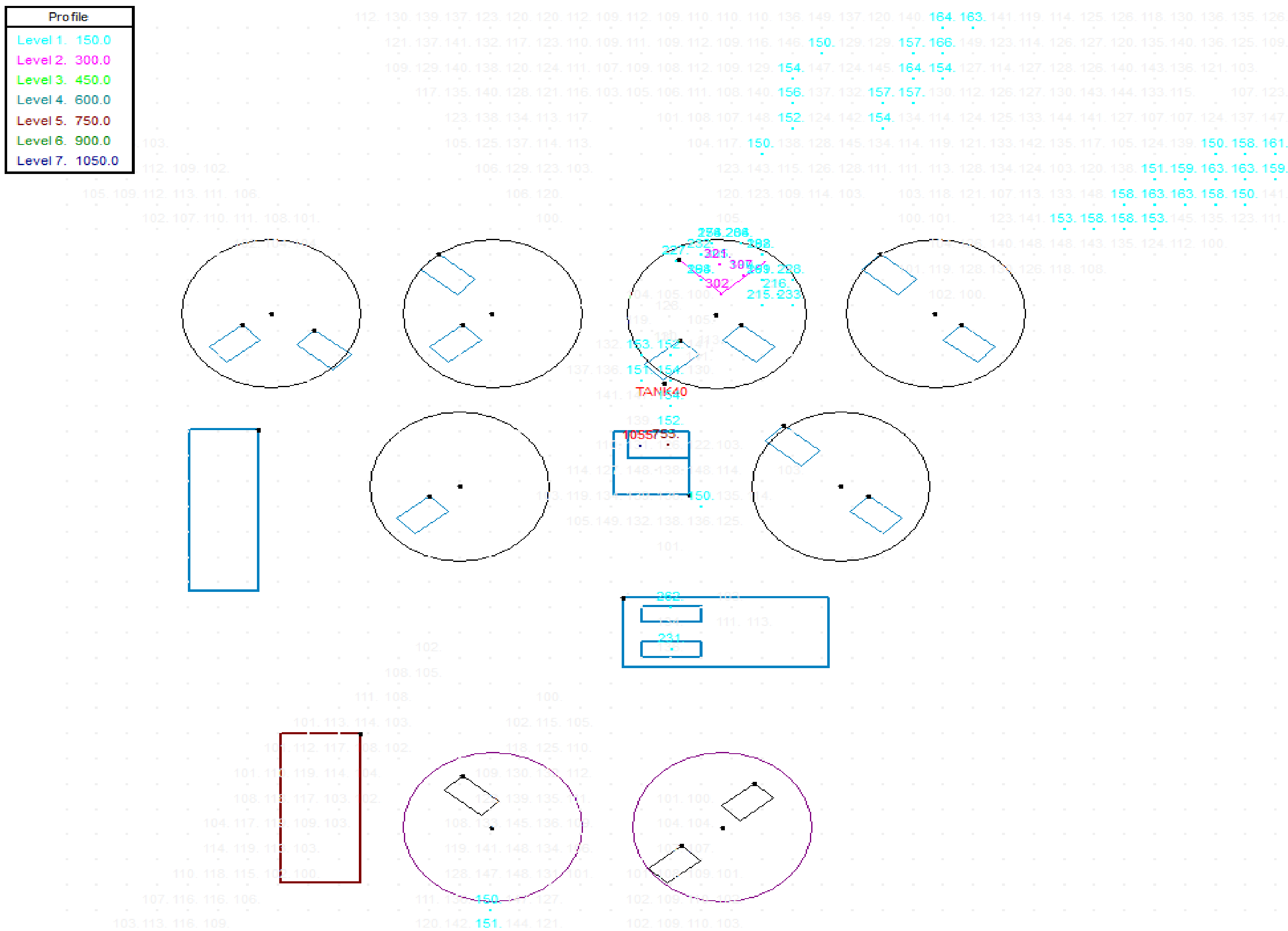

Figure 3-5. STEL Exceedances for Tank 40 with a 30-foot stack and 50 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

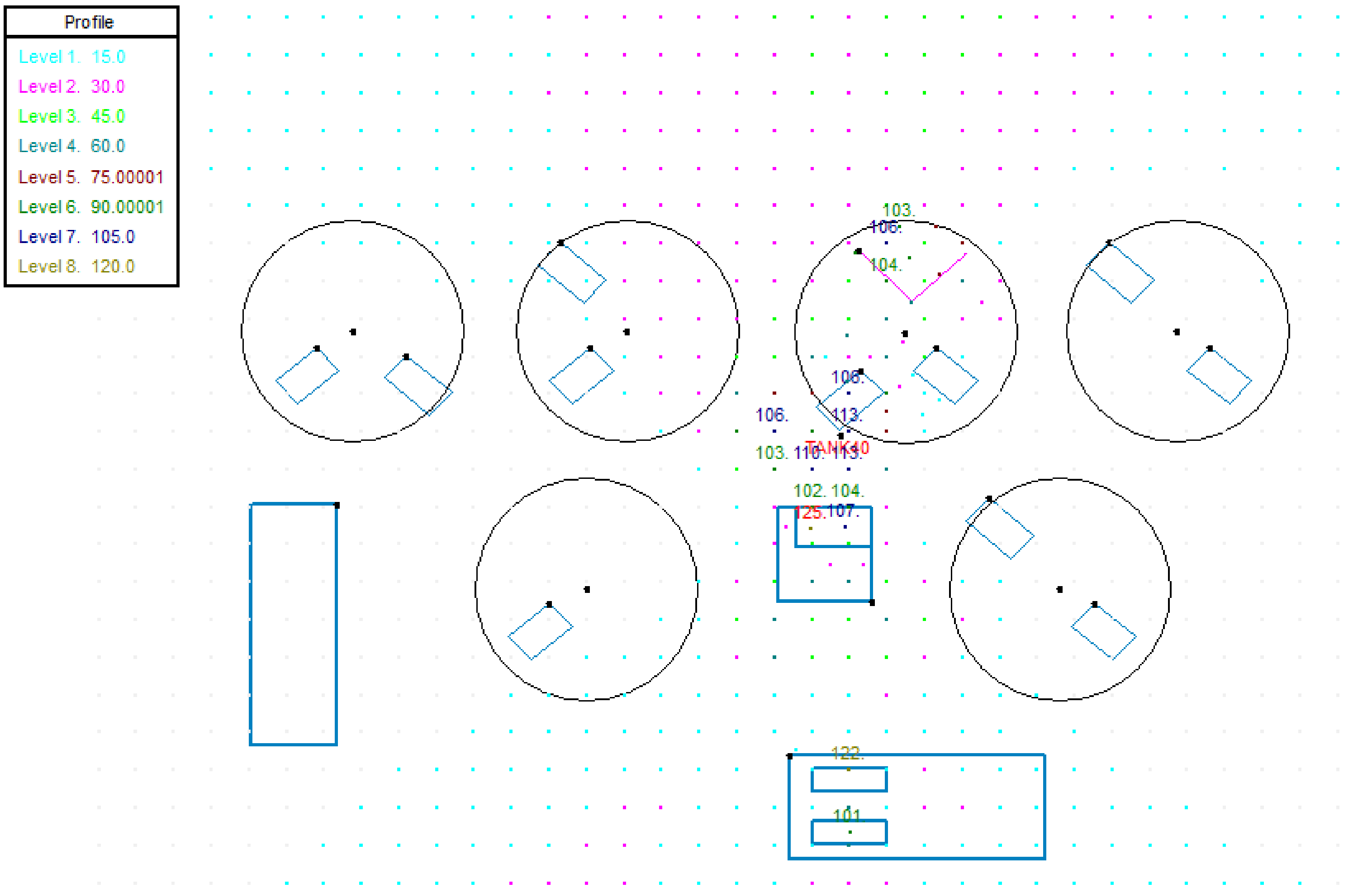

Figure 3-6. TLV Exceedances for Tank 40 with a 30-foot stack and 50 mg/m^3 release concentration scenario. Values are expressed as a percentage of the TLV standard (25 µg/m^3). Only values above 100% of the standard are displayed.

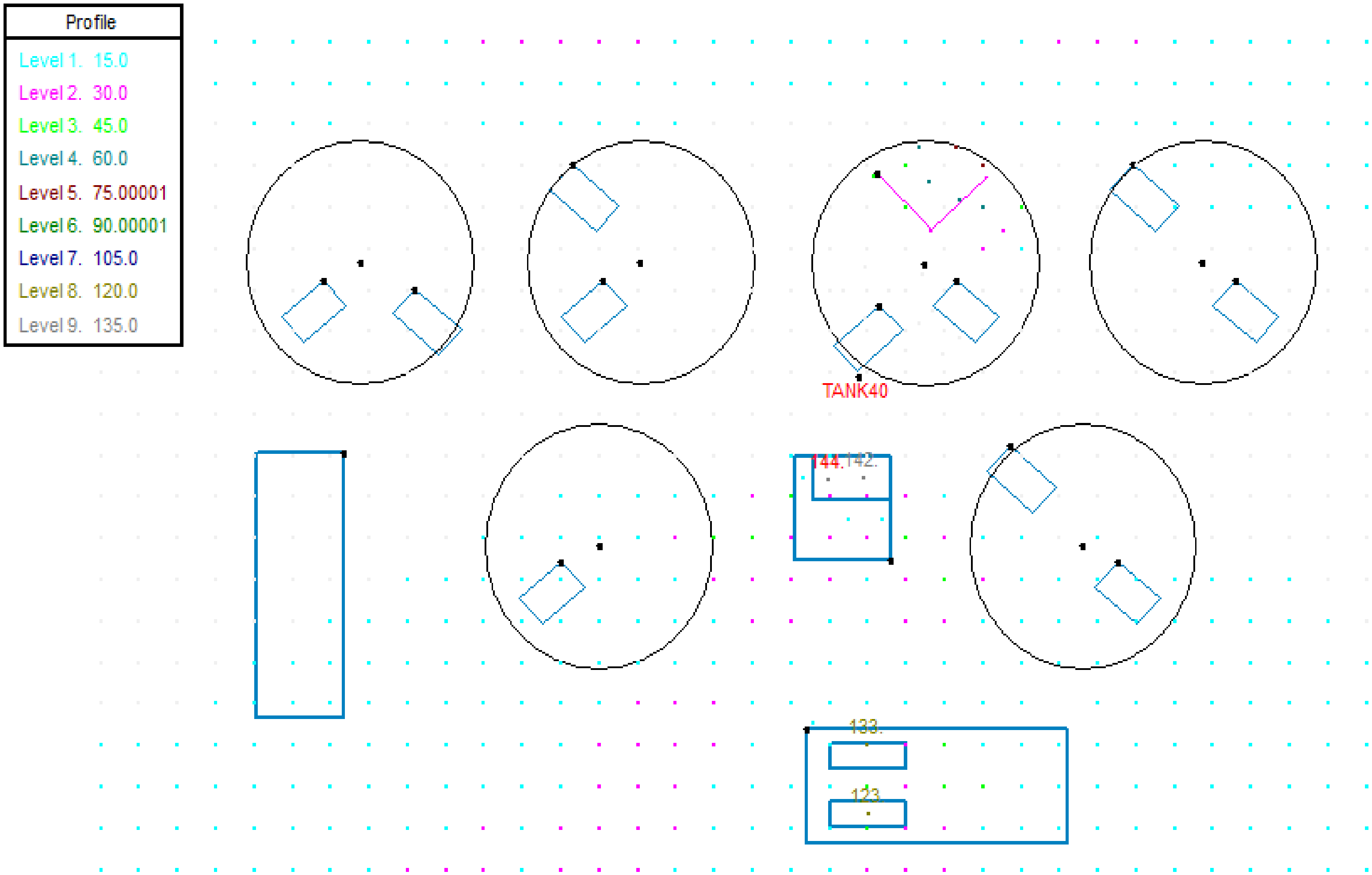

Figure 3-7. STEL Exceedances for Tank 40 with a 40-foot stack and 50 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

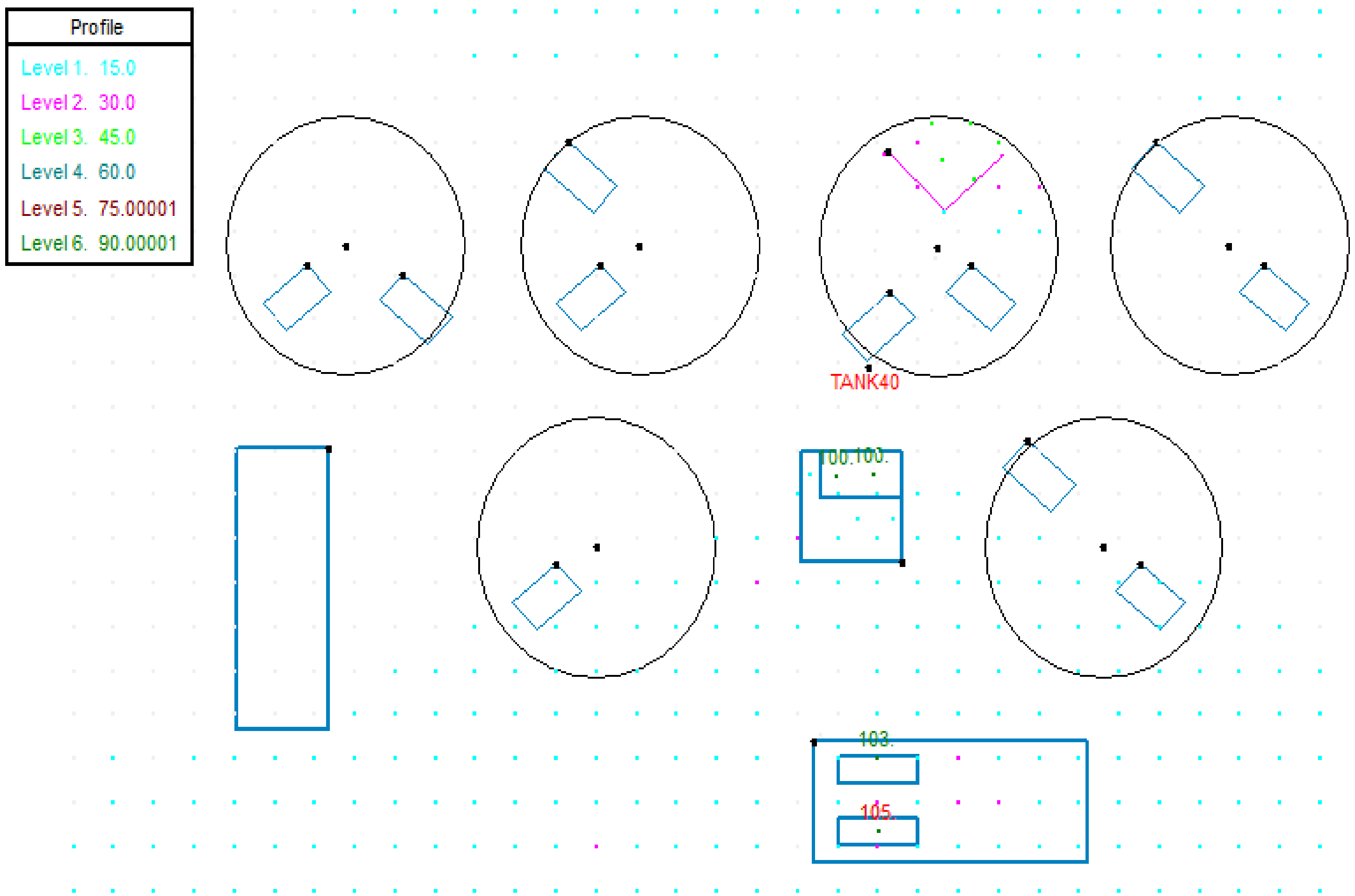

Figure 3-8. STEL Exceedances for Tank 40 with a 42-foot stack and 50 mg/m^3 release concentration scenario. Values are expressed as a percentage of the STEL standard (30 µg/m^3). Only values above 100% of the standard are displayed.

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