Evaluation of ATM 400 Permanent Durable Tape
Initial Report

December 2007

Report 2007 – 17
Reporting on Work Plan 2007-6

State of Vermont
Agency of Transportation
Materials and Research Section

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16. Abstract

In an effort to evaluate the service life of Durable tape, the Vermont Agency of Transportation applied an experimental pavement marking material, known as ATM 400, to a preexisting roadway on the Essex signal project, STPGSGNL (17) located at the intersection of VT Route 15 and VT 128 at MM 5.34 in the town of Essex in August of 2007.

The following report outlines the initial observations with regards to the application of two experimental permanent marking tapes, known as ATM 300 and ATM 400, with respect to letters, stop bars and crosswalks. In addition the report contains information pertaining to field data collection to assess the durability and luminance of the markings over time.

Overall, there are some concerns related to the ease of application, associated driver delays, recommended application temperatures and required unison between the pavement contractor and line striping company. However, preliminary retroreflectivity results are encouraging, well above national standards. In addition, as this product is inlaid, it may be less vulnerable to winter maintenance practices resulting in greater durability over time.

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INTRODUCTION:

Pavement markings provide an important means of communication for all roadway users and must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting. However, traffic markings are often subject to abrasion from tire treads and winter maintenance practices as well as ultraviolet sunlight and fading pigments following application. These factors result in altered color, a loss of binder and loss of reflective elements over time. Durable markings are often applied to newly constructed pavements in the state of Vermont and re-striped with waterborne paint when warranted. According to the "2006 Standard Specifications for Construction", "durable pavement markings are classified as pavement marking tape, epoxy paint, thermoplastic markings, polyurea paint, and methyl-methacrylate." Each of the referenced markings, comprised of various elements, has been shown to display unique characteristics and varying life cycles.

Durable tapes vary greatly from other liquid applied markings as they are manufactured under controlled conditions which may allow for more consistency in the product whereas markings such as thermoplastic and polyurea are applied in a liquid form to the road surface. Glass beads, which allow drivers to see pavement markings at night, are also incorporated into the material during the tape manufacturing process versus a drop on application for liquid markings. Finally, in accordance with our specifications, pavement marking tapes, when used as durable markings, are to be inlaid into the pavement during compaction of the hot mix asphalt or HMA whereas liquid markings are surface applied following roadway construction.

A recent statewide investigation of various pavement markings proved that winter maintenance practices are one of the largest factors that influence marking decay due to shearing effects produced by plow operations. If properly inlaid, durable tapes should be less vulnerable to winter maintenance practices as the surface of the marking should be level to the surface of the pavement. However, durable tapes have a higher average initial cost making them a less viable alternative to other markings, such as thermoplastic. Finally, durable tapes should be more tolerant of varying pavement surface textures as a roughened surface will distribute liquid line striping substrates over a larger surface area per unit area, generating an inconsistent thickness or inadequate thickness for the larger diameter beads resulting in premature bead loss. However, a greater surface area between the underlying pavement and tape may produce a greater or more consistent bond.

As a final consideration, traffic markings may be in the form of longitudinal markers, transverse markers, words and symbols. These may be subject to differing rates of decay given their position within the roadway. For instance, center lines, a longitudinal marking, segregates traffic in opposing directions and indicate where passing is permissible. Longitudinal markings are typically located along the shoulder and centerline of a roadway as opposed to words and symbols that are generally applied within the driving lane. Markings within the driving lane may be subjected to additional wear from tire treads and damage produced by snow plows due to their position within the roadway. Additionally, friction is generated between tire treads and roadway surfaces when brakes are applied potentially resulting in heightened wear.

The following report outlines the initial observations with regards to the application of two experimental permanent marking tapes, known as ATM 300 and ATM 400, with respect to letters, stop bars and crosswalks. In addition the report contains information pertaining to field data collection to assess the durability and luminance of the markings over time. Please note that no control, or standard marking materials, was applied in conjunction with this project.

PROJECT DETAILS:

In association with a federally approved work plan, WP 2007-6, all pavement markings, including letters, stops bars and crosswalks were applied to the Essex signal project, STPG SGNL (17) in the summer of 2007 located at the intersection of VT Route 15 and VT Route 128 at MM 5.34 in the town of Essex, shown in Figure 1 below. In accordance with the plans, this project included installing a new traffic signal system, upgrading pedestrian crossings, new signs, paving, and pavement markings to increase capacity and improve safety. Specifically, 2.5" of pavement were cold planed within project limits. The cold planed area was replaced with ½" of type IV leaving course and 2" of a type III wearing course. A Type III wearing course contains a nominal aggregate size of ½" resulting in a rougher pavement surface than a Type IV wearing course which contains a nominal aggregate size of 3/8". The average annual daily traffic (AADT) in 2006 was 15,800, a high AADT for a Vermont Route.

Figure 1 – Essex Intersection

As specified under the original contract plan, thermoplastic was to be applied throughout the limits of the project. However, the Resident, Greg Wilcox, was approached by one of the subcontractors, Scott's Line Striping, regarding the installation of permanent marking tape on the grounds that permanent tapes have proven to be more durable in high AADT locations. Once agreed upon by the Resident and project manager, Josh Schultz, the contract was modified for the application of permanent tape. ATM 400 tape was utilized for the letters and symbols as well as some of the stop bars and crosswalks, while ATM 300 tape was placed for the longitudinal markings and the remaining stop bars and crosswalks.

PRODUCT DETAILS:

According to the manufacturer, Advanced Traffic Markings, Inc. from Roanoke Rapids, NC, ATM 400 Permanent Durable Tape is lead free and environmentally safe. Reportedly, it meets or exceeds ASTM D4505, "Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life" and is marketed as a tape consisting of high quality polymeric materials, pigments, and glass beads to assure long term retroreflectivity. It's pre-applied, pressure sensitive adhesive minimizes tape movement in hot and cold climates. The ATM adhesive system is claimed to extend the application season as well. When applied in accordance with the manufacturer's recommendations it will adhere to asphalt or Portland cement roadway surfaces and should provide a minimum service period of 24 months in a moderate to heavy traffic volume.

ATM 400 Permanent Durable Tape is the manufacturer's "heavy grade" permanent tape (as opposed to the moderate grade 300 series). The tape is recommended for use in both longitudinal and transverse applications. It is a minimum of 90mil (2.29mm) thick to resist wear and provide extended life. The tape offers optional anti-skid particles and should have an initial minimum skid resistance of 55 BPN when tested according to ASTM E 303-83, "Test Method for Measuring Surface Frictional Properties Using the Bridge Pendulum Tester." The inlay method requires pavement temperatures of 120°F to 175°F. ATM 300 tape is comprised of the same components, however it varies from the ATM 400 tape in that is a minimum of 60 mils thick with an anticipated minimum service life of 16 months. All specifications and application instructions are provided in Appendix A.

INSTALLATION:

Application of the ATM 400 and ATM 300 permanent tapes was completed on Saturday, August 4th, 2007. According to Weatherunderground.com, the mean temperature was 72°F with an average humidity of 57% and no precipitation. As stated previously, Scott's Line Striping was the subcontractor on the project. In addition to the contractor, the project resident was also onsite to examine the application of the permanent tape.

Scott's Line striping monitored the apparent temperature of the HMA following initial compaction efforts to determine the appropriate time for the placement of the permanent marking tape. With respect to the longitudinal markings, once the pavement cooled to acceptable temperatures, the striping company offset the placement of the centerline marking from the pavement joint so that the marking material would not be applied directly over the joint. After the centerline was established, both white edge lines were marked in accordance with the plans. Then a handcart was used to apply the marking tape. The handcart was equipped with a special cutting blade providing a nice even finish. Finally, the final pavement rolling pattern was used for compaction of the HMA and inlaid the tape into place. Please note that this process does require special attention to sequencing. If utilized for a great length, this process may affect the rate of pavement laydown.

According to the daily reports "this method worked well although there were some areas that seemed to be applied at too hot a temperature as the tape stretched and then when it

cooled it pulled the mix apart which left a void". Figure 2 displayed below depicts a spot where shrinkage (void) has occurred during application. As stated previously, the manufacturers recommended surface temperature for application is 120°F to 175°F. This shrinkage should be minimized by applying the tape at proper pavement temperature. However according to the Greg Wilcox all the temperature readings were well within the manufacturer's specifications (125°F to 163°F). According to correspondence, Greg Wilcox wrote "my observations lead me to conclude that the tape could/should be laid down at even lower temperatures, say nothing above 140°F. Also the contractor should have a plan to fix areas that stretched and then cooled." Interestingly, application literature states, "if tape distorts or wrinkles, surface temperature may be too hot or roller speed may be too fast." Appendix B contains a summary of project locations and pavement application temperatures at each test site along with other pertinent information. The average pavement temperature at the time of installation for ATM 400 tape was calculated to be 138°F, while the average temperature for ATM 300 tape was slightly higher at 144°F. As a final consideration, the daily report also states that "the in-laid tape added to the traffic delays because the crew was laying out and working areas that could be used for traffic."

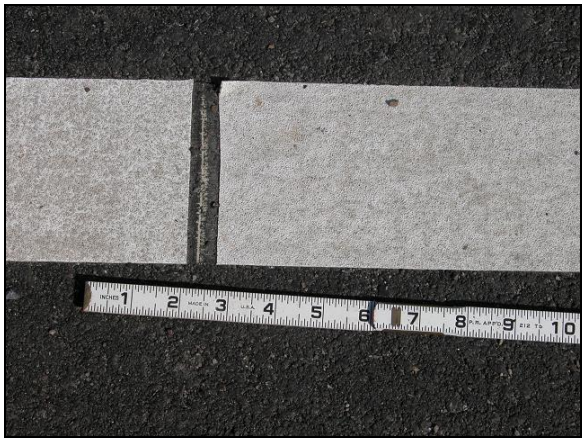


Figure 2 – Void Between Tape Segments

SURVEILLANCE AND TESTING:

In addition to monitoring surface temperature during application, five test sites were established throughout the length of the project in order to collect retroreflectivity readings in accordance with ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Potable Retroreflectometer", and durability, in accordance with ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint." Test sites one through three, and four through five were identified within areas containing ATM 400 and ATM 300 permanent tape, respectively. Test sites one, two and four were located along the crosswalk with readings collected on every other marking. Test site three was positioned across the stop bar at the end of the right turn only lane along VT Route 15 with readings collected in two foot increments. Test site five was established along the southeast longitudinal white edge line marking within the intersection with markings collected every ten feet. Please see Appendix B for a detailed map of all test sites. Each data collection location was identified with white marking paint in order to ensure that all future readings will be collected from the same location.

Retroreflectivity readings and visual assessments were collected utilizing a LTL 2000 retroreflectometer which employs 30 meter geometry. Photographic documentation was also gathered at individual test site locations during each field visit. All retroreflectivity and durability readings were recorded onto the appropriate field forms and then compiled into a dedicated spreadsheet. Initial site visits were conducted on August 10th, August 15th, and August 30th, 6 days, 11 days, and 26 days following application, respectively. All pavement markings were found to be intact. A summary of initial retroreflectivity readings are provided below in Table 1 and Table 2. Please note that all of the experimental markings, including both the ATM 400 and 300 series, were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" which requires a minimum retroreflectivity of 250 mcdl for white markings within 14 days of application.

Retroreflectivity Readings for ATM 400 Tape			
Test Site ID:	**08/10/2007**	**08/15/2007**	**08/30/2007**
TS1 – East Crosswalk	1100	1145	928
	1003	925	522
	1182	1118	930
	1102	909	607
	1368	1250	1023
	694	992	1007
Average	1075	1057	836
Std. Dev.	223	136	216
TS2 – West Crosswalk	1184	1161	427
	1196	896	162
	1236	1123	666
	1012	1009	942
	354	295	706
	428	430	519
Average	902	819	570
Std. Dev.	404	368	267
TS3 – Stop Bar, West Side, Right Turn Lane	912	780	504
	1195	1141	967
	1152	932	552
	1124	932	760
	1207	1200	984
Average	1118	997	753
Std. Dev.	465	431	364
Overall Average	**1026**	**955**	**718**

Table 1 – ATM 400 Retroreflectivity Readings

Retroreflectivity Readings for ATM 300 Tape			
Test Site ID:	**8/10/2007**	**8/15/2007**	**8/30/2007**
TS4 - Tower Rd. Crosswalk	526	845	870
	436	308	905
	725	678	567
	995	734	606
	934	852	223
	743	597	297
Average	727	669	578
Std. Dev.	219	202	282
TS5 - White Edge Line Route 15	678	559	374
	718	694	489
	665	638	553
	689	655	555
	769	701	555
	709	595	610
Average	705	640	523
Std. Dev.	37	56	82
Overall Average	**716**	**655**	**550**

Table 2 – ATM 300 Retroreflectivity Readings

COSTS:

All costs for the application of the marking and marking materials were paid for as part of the construction project for a total longitudinal length of 0.124 miles (660 linear feet). Specifically, this was to include all white and yellow pavement markings, as well as stop bars, crosswalk markings, and lettering. ATM 400 permanent marking tape generally costs $\$3.25/ft^2$. This is equivalent to \$1.08/LF for a 4" wide line. The cost for the ATM 400 tape including materials and installation was as follows: \$150 for the letters, \$1320 for the stop bars, and \$1560 for the crosswalks. Advanced Traffic Markings agreed to supply the state with 1900 LF of 4" durable white line, 650 LF of durable 4" yellow line, 75 LF of durable 24" wide stop bars, 190 LF of durable crosswalk markings with diagonal lines, and 22 durable letters and symbols, as shown within the quantity sheets of the project plans. Table 3 below shows the quantity of the products that was used on the project.

Marking Type	Quantity
ATM 300 Durable 4" White Line	1900 LF
ATM 300 Durable 4" Yellow Line	650 LF
ATM 300 & 400 Durable 24" Stop Bar	75 LF
ATM 400 Durable Letter or Symbol	22 Units
ATM 300 & 400 Durable Crosswalk Marking w/ Diag. Lines	190 LF

Table 3 – Product Quantities

DISCUSSION:

Two experimental permanent pavement marking tapes, known as ATM 400 and ATM 300, were applied to the Essex signal project, STPG SGNL (17) located at the intersection of VT Route 15 and VT Route 128 at MM 5.34 in the town of Essex on Saturday, August 4th by personnel from Scott's Line Striping. This process was somewhat labor intensive as compared to the installation of liquid pavement markings, such as thermoplastic and polyurea, and had to be accomplished in concert with the construction of the hot mix asphalt. Basically, the striping crew delineated the future placement of the centerline which was offset from the joint along with the white edge lines. Following initial compaction of the HMA, the surface of the pavement was allowed to cool to a recommended temperature range of 120°F to 175°F. Then the permanent tape was applied through the use of a hand cart. Finally, the tape was inlaid into the pavement during final compaction efforts. Remarks from the Project Resident indicated extended traffic delays and some concerns regarding application temperature with consideration to apparent shrinkage. However, temporary markings are not needed in the process unlike most liquid marking applications which generally require a large portion of the project to be completed prior to installation to reduce overall costs. No control, or standard marking material, was applied in conjunction with this project.

All of the white experimental markings were found to be well above the current minimum retroreflectivity requirements immediately following application with values of 250 mcdl for newly applied pavement marking within 14 days of application as stated within ASTM standard, ASTM D 6359-99. As would be expected, the ATM 400 displayed higher initial luminance of 1026 mcdl six days following application as compared to ATM 300 with an average retroreflectivity of 716 mcdl. However, there are some concerns related to measured losses on retroreflectivity over the referenced monitoring period. Within 20 days, an overall average loss of 308 mcdl and 166 mcdl was observed in the ATM 400 and ATM 300 markings, respectively. Standard deviations within the ATM 400 series are quite large as well, 420 mcdl on average throughout the rating period, indicating large variability of the data sets. Conversely, the standard deviations for the ATM 300 series are relatively small, 55 mcdl on average, which suggests consistency within the marking material.

Overall, there are some concerns related to the ease of application, associated driver delays, recommended application temperatures and required coordination of tasks between the pavement contractor and line striping company. However, preliminary retroreflectivity results are encouraging, well above national standards. In addition, as this product is inlaid, it may be less vulnerable to winter maintenance practices resulting in greater durability over time.

FOLLOWUP:

Research personnel will continue to monitor the permanent tape markings and collect durability and retroreflectivity readings in accordance with the research work program. Minimum reported service lives of 24 months for the ATM 400 tape and 16 months for the ATM 300 series will be assessed. In addition, information regarding the impact of winter maintenance practices with consideration to durability will also be examined. A final report will be published evaluating the overall performance of the ATM 400 and

300 series along with future recommendations for placement. A service life cost analysis will also be performed.

REFERENCES:

ASTM D 4505, "Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life," ASTM International, West Conshohocken, PA, <www.astm.org>.

ASTM D 6359-99, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments," ASTM International, West Conshohocken, PA, <www.astm.org>.

ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint," ASTM International, West Conshohocken, PA, <www.astm.org>.

ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer," ASTM International, West Conshohocken, PA, <www.astm.org>.

ASTM E 303-83, "Test Method for Measuring Surface Frictional Properties Using the Bridge Pendulum Tester," ASTM International, West Conshohocken, PA, <www.astm.org>.

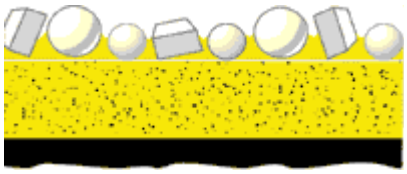
Fitch, Jennifer and Crum, Nicole. *Work Plan for Research Investigation: ATM 400 Permanent Durable Tape, Work Plan No. WP-2007-6*. Vermont Agency of Transportation, 2007.

Vermont Agency of Transportation. *2006 Standard Specifications for Construction*. 2006

Weather Underground. 8 October 2007. <http://www.wunderground.com/>

APPENDIX A

ATM Permanent Series 300 & 400
Preformed Polymer Tape
***Specifications*[1]**



- Meets Or Exceeds ASTM D4505-01a Standard Specification For Preformed Retroreflective Pavement Marking Tape For Extended Service Life

Series 300 Durable preformed plastic, permanent marking tapes are designed for usage on asphaltic or concrete surfaces. Series 300 tapes are suitable for longitudinal markings and transverse markings including word/symbol markings. Series 300 Durable tape is available in white, yellow and custom colors.

Series 400 Extended Life preformed plastic, permanent marking tapes are designed for usage on asphaltic or concrete surfaces. Series 400 tapes are suitable for longitudinal markings and transverse markings including word/symbol markings. Series 400 Extended Life tape is available in white, yellow and custom colors.

PHYSICAL PROPERTIES

Composition: All Permanent Series Tapes consists of a pre-applied, pressure sensitive adhesive with high quality polymeric materials, pigments and glass beads assuring long term retroreflectivity.

Applicability To Pavement Surfaces: Ambient temperatures, 24 hours before and after, of 50°F (10°C) and rising. See Manufacturers Application Instructions included in each box.

Adhesion: Permanent Series Tapes will adhere to asphalt or portland cement concrete roadway surfaces when applied according to the manufacturer's recommended procedures.

Pigmentation: Permanent Series Tape pigments are selected and blended to provide a marking tape in white or yellow conforming to standard highway colors.

Skid Resistance: Permanent Series 300 and 400 tapes will have an initial minimum skid resistance value of 55 BPN when tested according to ASTM E 303.

Reflectance: Permanent Series Tapes have the following minimum results when tested in accordance with ASTM D4061.

	White		Yellow	
Entrance Angle-Degrees	86.0	86.0	86.0	86.0
Observation Angle-Degrees	0.2	0.5	0.2	0.5
Specific Luminance (mcd ft^{-2} $(fc)^{-1}$)	1770	1270	1310	1000
LTL 2000 Reflectometer	800		600	

Performance Requirements: Series 300 tape, when applied according to the manufacturer's recommendations, shall provide a minimum service period of 24 months in light to moderate traffic volume.

Series 400 tape, when applied according to the manufacturer's recommendations, shall provide a minimum service period of 36 months in moderate to heavy traffic volume.

In snow removal areas, plowing may shorten tape's life cycle.

Series 300 and 400 are also available with extended four and six year warranties. Please contact your ATM Sales Representative for specifications.

[1] From http://www.trafficmarkings.com/atm_400_tape_specs.html

ATM PERMANENT PREFORMED POLYMER TAPES APPLICATION INSTRUCTIONS[2]

Overlay Method

- Air and surface temperature must be 50°F (10°C) and rising.
- Surface must be completely dry.
- Surface must be clean and free of any contaminants which may include but not limited to oils, grease, sand, dirt, dust, loose aggregate, curing compound, mud, soil and salt.
- Portland Cement concrete curing compound must be completely removed by pressure washing, sandblasting, or grinding the road surface.
- ALWAYS USE BUTT SPLICES.
- Do not apply tape directly over deteriorating markings or substrates, or lane delineation devices.
- Tapes or Rumble Strips applied directly over seams and joints must be cut through 1" on both sides of the joints or seams to prevent de-bonding of large sections of tape.
- Apply an ATM primer on all surfaces except newly laid asphalt, up to one year and in good to excellent condition. Allow adhesive to completely dry before installing the markings.
- Use ATM Permanent Primer on completely cured surfaces if it has rained 6 hours prior to, or it is expected 24 hours after installation.
- Firmly tamp longitudinal tape in the same direction as tape was applied on the initial pass. A minimum of three passes total are required. Use a tamper device with a minimum 200 lb. (90kg) load and a tamping surface a minimum 2" wider than the width of tape being applied. Never twist the tampering device during tamping. Repeat tamping as necessary to insure tape has completely conformed to the road surface.
- Marked roadway can be open to traffic immediately.
- Firmly tamp transverse marking symbol/legends using an approved ATM Tamper Cart with a minimum 200lb./90kg load. A minimum of three passes total are required.

Inlay Method

General Conditions:

- Surface temperature must be 120°F (49°C) - 175°F (79°C)
- Do not attempt to inlay tape during rain.
- Apply tape only after initial compaction has taken place.

Application Procedures:

- Insure general conditions can be met.
- After compaction, mark surface where tape will be applied. DO NOT LAY TAPE ON SEAMS OR JOINTS
- Apply tape either by hand or with the ATM Tape Applicator Cart.
- ALWAYS USE BUTT SPLICES.
- Finish rolling pavement surface.

NOTE: IF TAPE DISTORTS OR WRINKLES, SURFACE TEMPERATURE MAY BE TOO HOT OR ROLLER SPEED MAY BE TOO FAST.

[2] From http://www.trafficmarkings.com/overlay.html

APPENDIX B

Type of Line	Pavement Temp (°F)	ATM Tape Series	Station
Symbol	138	400	280+13 Lt
Symbol	127	400	280+13 Rt
Letters	142	400	280+50 Lt
Letters	125	400	280+50 Rt
Symbol	135	400	280+86 Lt
Symbol	140	400	280+86 Rt
Stop Bar	133	400	280+99 Lt to CL
TS 3 Stop Bar	**140**	**400**	**281+19 CL to Rt**
TS 2 Crosswalk	**137**	**400**	**281+28 Lt to Rt**
TS 1 Crosswalk	**150**	**400**	**282+28 Rt to CL**
TS 1 Crosswalk	**137**	**400**	**282+28 CL to Lt**
Stop Bar	150	400	282+37 CL to Rt
Crosswalk	145	300	0+51 CL to Lt
Crosswalk	136	300	0+51 CL to Lt
Stop Bar	140	300	0+60 Lt
TS 4 Crosswalk	**163**	**300**	**10+44 CL to Lt**
TS 4 Crosswalk	**155**	**300**	**10+44 CL to Rt**
Stop Bar	132	300	10+63 CL to Lt
Double Yellow	135	300	279+50 to 281+00
Double Yellow	144 start, 156 end	300	282+36 to 284+00
Double Yellow	145	300	0+59 to 1+50
Double Yellow	137	300	10+64 to 11+50
TS 5 4” White Edge Line	**150 start, 135 end**	**300**	**279+50 Rt to 282+95 Rt**
4” White Edge Line	149	300	284+00 Lt to 1+50 Rt
4” White Edge Line	160	300	1+50 Lt to 11+50 Rt
4” White Edge Line	129	300	11+50 Lt to 279+50 Lt

Stations of 279+50 through 284+00 refer to Route 15
Stations of 10+00 through 11+50 refer to Towers Road
Stations of 0+00 through 1+50 refer to VT 128
Bold indicates retroreflectivity test sites

Table B1 – Pavement temperatures at time of all ATM tape installations

A complete list of all ATM tape installations for this project is provided in Table B1. The type and purpose of each tape placement is listed along with the exact stationing of each and the associated pavement temperatures at time of installation. Two entries have multiple temperatures listed, as these applications were done in multiple sections.

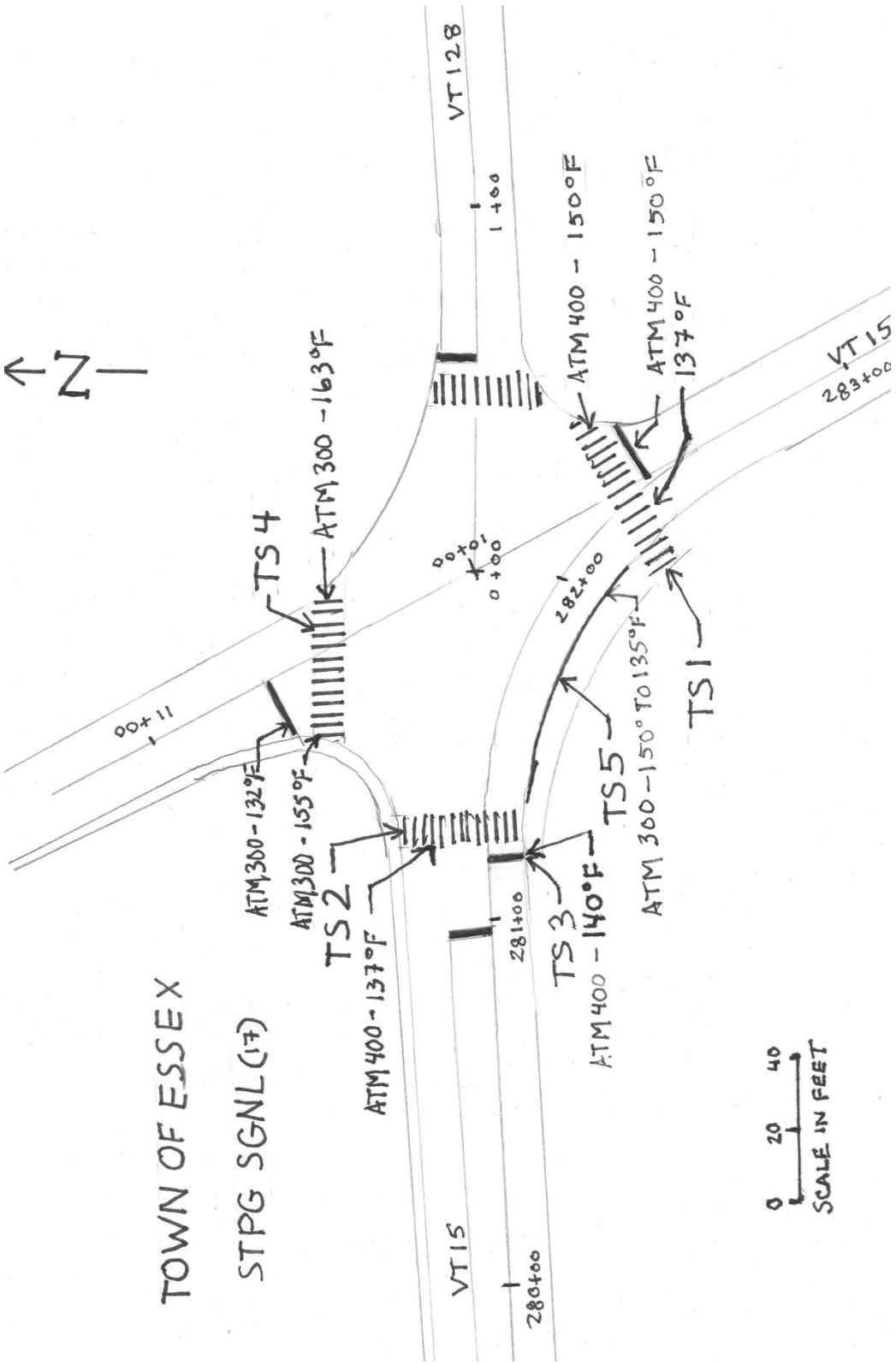


Figure B1 – Diagram of VT 15 and VT 128 intersection

A diagram of the entire project is provided in Figure B1. Included in the diagram are the locations of the five test sites selected for retroreflectivity measurement, along with the associated pavement temperatures at the time of ATM tape installation at each site.