



## Standard Practice for Conducting Case Studies on Galvanized Structures<sup>1</sup>

This standard is issued under the fixed designation A 896; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice sets forth the procedures for conducting case studies of galvanized installations. It is intended for structural members and other permanent parts of the installation, such as railings and other such fabrications.

1.2 Included in this practice are recommendations for the visual inspection of the galvanized structure, measurement of coating thickness, and reporting of results.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

2.1 *ASTM Standards:*

B 499 Test Method for Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals<sup>2</sup>

E 376 Practice for Measuring Coating Thicknesses by Magnetic-Field or Eddy Current (Electromagnetic) Test Methods<sup>3</sup>

### 3. Significance and Use

3.1 This practice is applicable to galvanized structures exposed to the atmosphere or to plant environments, including buildings, bridges, and industrial plant constructions.

3.2 It provides for the collection of data to document the protection afforded by the galvanized coating.

3.3 Method A for conducting a coating thickness survey aims essentially at an assessment of the general condition of the galvanized structure, at the time of the inspection, by taking thickness measurements on several members of the structure.

3.4 Method B provides for accurate monitoring of the coating thickness decrease as a function of time, at specific locations on the structure, in order to assess the corrosivity of the environment, the effect of orientation, elevation, or other factors.

3.5 Method B is not an alternate procedure to Method A, but is complementary and optional.

### 4. Apparatus

4.1 *Surface Preparation:*

4.1.1 *Water.*

4.1.2 *Cloths*, for washing and drying.

4.1.3 *Soft Fiber Bristle Brush.*

4.2 *Coating Thickness Measurement:*

4.2.1 *Thickness Gage.*

4.2.2 *Steel Calibration Plates and Foils.*

4.2.3 *Permanent Marker.*

4.2.4 *Tape Measure.*

4.2.5 *Center Punch.*

4.2.6 *Hammer.*

4.3 *Electronic Magnetic Flux Gage*—The use of an electronic magnetic-flux gage in accordance with Method B 499 is recommended. Instruments with an accuracy of  $\pm 3$  to  $\pm 5$  % are commercially available.

4.3.1 Probes having a constant pressure feature will minimize operator error.

4.3.2 The probe assembly should have a probe support if measurements are to be made on rounded or curved surfaces.

4.4 *Hand-Held Magnetic Gage*—A hand-held magnetic gage using the magnetic attraction principle in accordance with Practice E 376 may be used for Method A.

### 5. General Procedure

5.1 *Background Information:*

5.1.1 Wherever possible, obtain information on the tonnage and cost of the steel work, the cost of galvanizing, and estimates of alternative coating costs (initial and maintenance) if the steelwork had been coated by another method. Determine if there are areas of the installation which were painted rather than galvanized, or painted over galvanizing.

5.1.2 Determine if any problems were experienced during fabrication, galvanizing, construction, and operation.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 03.03.

## 5.2 Corrosive Environment Identification:

5.2.1 The galvanized installation should be divided according to the various corrosive environments to which it is exposed. For example, plant atmospheres could be categorized with respect to the processing step. Sheltered versus boldly exposed areas can be considered as two different environments.

5.2.2 Pertinent data relating to the corrosive environments should be obtained, such as types of chemical present, concentration of fumes, occurrence of spills, temperature fluctuations, amount of rainfall, or the use of de-icing salts.

## 5.3 Visual Inspection:

5.3.1 Observe the overall appearance of the galvanized structure, and the appearance of each type of plant environment, if applicable. Note such characteristics as color and spangle of the galvanized coating, the presence of rust or staining, and the condition of other coatings, such as paint. Take note of chemical spills or leaks, the presence of fumes or high humidity, and effects of orientation, elevation, design, or any other factors causing localized or nonuniform corrosion.

5.3.2 The condition of the galvanized coating may vary according to section thickness or geometry of the steel. For example, there may be differences with respect to light versus heavy sections or handrails versus beams.

5.3.3 The use of high silicon steels may be apparent, and should be noted.

5.3.4 Fasteners should be inspected. Look for rust, staining, or mechanical damage.

## 5.4 Coating Thickness Survey:

### 5.4.1 Method A:

5.4.1.1 The selection of structural members should be based mainly on the section thickness. A minimum of three representative members from each of the two categories of section thickness, light (bracing) and heavy (column, beam) should be surveyed for each corrosive environment. Selection of suitable locations for coating thickness measurements is at the discretion of the inspector and may be based on factors such as orientation or accessibility. Take measurements in areas where the coating is uniform.

5.4.1.2 Fasteners should be surveyed where their size permits. Measurements should be made on the center of bolt heads, or on the flat parts of bolt heads or nuts.

5.4.1.3 Calibrate the coating thickness gage against proper reference materials before making measurements.

5.4.1.4 Clean the surface, using a fine fiber brush or by washing with water and drying, or both. Avoid removing any of the coating material or the film of basic zinc salts.

5.4.1.5 At each location, make a minimum of five measurements and determine the mean coating thickness.

### 5.4.2 Method B:

5.4.2.1 A minimum of three locations should be surveyed for each corrosive condition or position of interest. The locations need not be on the same steel member. Selection of suitable locations is at the discretion of the inspector. Take measurements in areas where the coating is uniform.

5.4.2.2 Calibrate the coating thickness gage with proper reference materials before the survey is started. Calibrations should be checked periodically to ensure continued accuracy of measurements and again at the end of the survey.

5.4.2.3 Clean the surface, using a fine fiber bristle brush or by washing with water to remove dirt and dust, or both.

Note: **Caution**—Do not abrade with emery paper or wire brush, or clean in any manner that would tend to remove the zinc coating or the film of basic zinc salts. By removing the basic zinc salts film, corrosion can be accelerated.

5.4.2.4 Twenty-five measurements should be made at each location within an area 50 by 50 mm (2 by 2 in.) square, and the mean ( $\bar{X}$ ) and the 90 % confidence limit on the mean ( $S_{m90}$ ) should be determined (see Appendix X1). A different test area should be surveyed if  $S_{m90}$  is greater than 6  $\mu\text{m}$  (0.3 mil). If possible, use a template with 25 small holes (approximately 4 mm diameter) in a 5 by 5 grid, with outside corner measurements 50 by 50 mm (2 by 2 in.). Holes should be 12.5 mm (0.5 in.) apart horizontally and vertically. The grid should be centered in a larger square measuring 75 by 75 mm (3 by 3 in.) with outside corners containing small holes (see Fig. 1). Put the template on the cleaned surface and mark the 29 holes with a felt tip marker. Measurements are to be taken starting with the top left and recorded on the report form in the same order as measured on the grid.

5.4.2.5 To make test areas easier to locate for future surveys, center punch the outside corners of the 75 by 75 mm square (3 by 3 in.) so identification marks do not interfere with coating measurements. If punching is not possible, use paint or other permanent marker (less desirable). If possible, take a photographic record to properly document the position of each structural member on which measurements were made in relation to the plant layout.

5.4.2.6 Periodic surveys should be conducted. An initial two-year interval is recommended for the first several years. Depending on the nature of the data collected at the time of the second inspection, longer intervals may be considered.

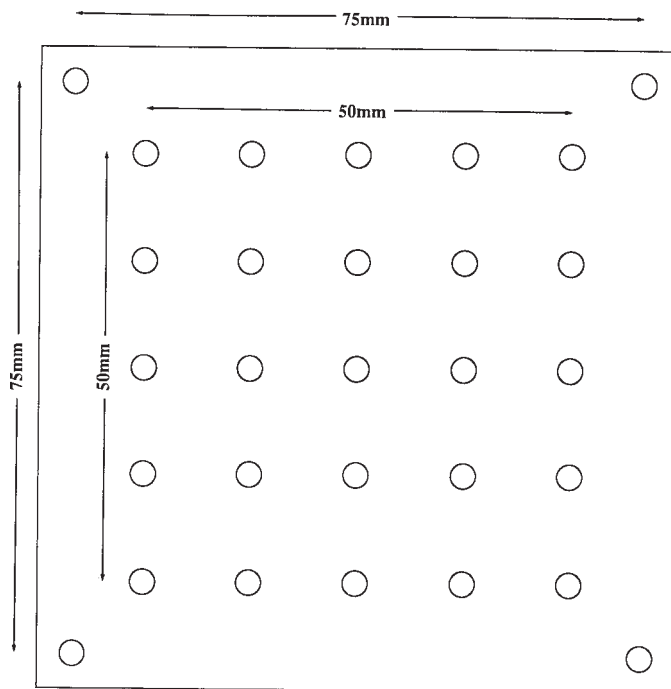


FIG. 1 Template (not to scale)



5.4.2.7 The same thickness gage, or at least the same type of instrument as used in subsequent surveys. The steel calibration plate should be the same for each survey.

#### 5.5 Photographs:

5.5.1 Obtain an overall photographic view of the installation, from several angles, if possible.

5.5.2 Photograph each corrosive environment where measurements are made, show the relation of the site to the general plant layout. If possible, show the fumes or chemicals that would normally be present.

5.5.3 Take close-up photographs where appropriate.

5.5.3.1 Include close-up photographs of areas where actual measurements were made.

5.5.3.2 Take close-up photographs of other areas pertinent to the study, such as those areas showing concentrated corrosion, coating damage, staining, etc., that is not typical of the galvanized structure as a whole.

5.5.3.3 Take close-ups of fasteners.

5.5.3.4 Take close-ups of painted or other coated areas.

### 6. Report

6.1 Report sheets are provided in Appendix X2.

6.2 State the name of the company of installation and its location. Describe the type of structure if an industrial plant.

6.3 The inspector should state his or her name, company contact, date of the inspection, and type of thickness measuring equipment used.

6.4 Present any data that is available regarding tonnage and cost of the steel, and comparison costs of galvanizing versus other coating systems.

#### 6.5 Visual Inspection:

6.5.1 Report the general appearance of the galvanized structure or installation, and any noticeable changes since the last inspection. Report coating characteristics such as color, spangle, stains, rust, and condition of paint coatings, fasteners, and high silicon steels within each type of environment, if applicable.

6.5.2 Relate the photographs to the locations discussed in the report.

#### 6.6 Coating Thickness Measurement:

6.6.1 *Method A*—State the range of average coating thicknesses measured on structural members, including high silicon steels, and on fasteners. Make mention of differences in coating thickness that may arise from such factors as section thickness, orientation, etc.

6.6.2 *Method B*—Provide details about each location at which thickness measurements were made and state the mean and the 90 % confidence interval, rounding to the least significant number of digits.

6.6.3 Relate photographs to the corresponding areas measured.

## APPENDICES

### (Nonmandatory Information)

#### X1. CALCULATION OF 90 % CONFIDENCE INTERVAL

X1.1 The standard deviation,  $s$ , of a series of measurements can be calculated using the following equation:

$$s = \sqrt{\frac{\sum[(X_i - \bar{X})^2]}{n - 1}}$$

where:

$X_i$  = each individual reading,

$\bar{X}$  = mean of group of 25 readings, and

$n$  = number of measurements.

X1.2 The 90 % confidence interval on the mean,  $S_{m90}$ , can be expressed as follows:

$$S_{m90} = \frac{ts}{\sqrt{n}}$$

where:

$s$  = standard deviation, and

$t$  = the  $t$  distribution value for  $n - 1$  degrees of freedom.

X1.2.1 Tables containing values for  $t$  can be found in textbooks on statistics or in most engineering handbooks. For the number of measurements ( $n = 25$ ) prescribed in 5.4.2.4,  $t = 1.711$  for  $n-1$  degrees of freedom and the value of

$$t/\sqrt{n} = 1.711/5 = 0.34.$$

The 90 % confidence interval on the mean for 25 measurements can then be written as  $S_{m90} = 0.34 s$ .

X1.2.2 If some number other than 25 measurements is used, the value of  $t$  for  $n-1$  degrees of freedom must be determined from statistical tables.

X1.2.2.1 Calculation of  $X$ ,  $s$ , and  $S_{m90}$  values can be tedious, and the use of an electronic calculator is recommended.

X1.3 The significance of  $S_{m90}$  is that there is a 90 % probability that the true value of the mean will lie within the range  $X \pm S_{m90}$ , the most probable value being  $X$ . A test program involving field measurements has shown that considering a corrosion rate of 2.5  $\mu\text{m}/\text{year}$  (0.1 mil/year), it will be possible to see a significant difference between average coating



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thicknesses resulting from surveys carried out ten years apart in time and based on 25 readings.

### X1.4 *Example of Calculations:*

X1.4.1  $X_i =$  142, 165, 170, 155, 168, 132, 163, 152, 179, 142, 157, 173, 152, 135, 170, 155, 165, 170, 165, 147, 152,

163, 152, 163, 160  $\mu\text{m}$  (5.6, 6.5, 6.7, 6.1, 6.6, 5.2, 6.4, 6.0, 7.0, 5.6, 6.2, 6.8, 6.0, 5.3, 6.7, 6.1, 6.5, 6.7, 6.5, 5.8, 6.0, 6.4, 6.0, 6.4, 6.3 mil).

X1.4.2 Mean,  $\bar{X} = 157 \mu\text{m}$  (6.2 mil).

X1.4.3 Standard deviation,  $s = 12 \mu\text{m}$  (0.5 mil).

X1.4.4 90 % confidence interval,  $S_{m90} = 4 \mu\text{m}$  (0.2 mil).

## X2. CASE STUDY REPORT SHEET

X2.1 Fig. X2.1 shows a case study report sheet.

**I. General Information**

Project/Installation Name \_\_\_\_\_

Type of Facility/General Description \_\_\_\_\_

Location \_\_\_\_\_

|  |      |         |         |       |
|--|------|---------|---------|-------|
|  | name | address | contact | phone |
|--|------|---------|---------|-------|

Company/End User \_\_\_\_\_

Engineer \_\_\_\_\_

Architect \_\_\_\_\_

General Contractor \_\_\_\_\_

Steel Fabricator \_\_\_\_\_

Galvanizer \_\_\_\_\_

|                                   |         |      |
|-----------------------------------|---------|------|
| Date of Construction _____/System | Tonnage | Cost |
|-----------------------------------|---------|------|

Galvanized \_\_\_\_\_

Painted \_\_\_\_\_

Paint over galvanized \_\_\_\_\_

Steel specifications/typical sections \_\_\_\_\_

**II. List of Corrosive Environments/Corrosive Agents**

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

4. \_\_\_\_\_

**III. Comments**

What prompted use of corrosion system(s), engineering objects, cost comparisons with other systems, different or unusual applications, etc.?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**IV. Visual Inspection (one report per corrosive environment)**

Project/installation name \_\_\_\_\_

Location \_\_\_\_\_

Inspection Date \_\_\_\_\_/

|  |      |      |         |       |
|--|------|------|---------|-------|
|  | name | firm | address | phone |
|--|------|------|---------|-------|

Inspector \_\_\_\_\_

Site Contact \_\_\_\_\_

Corrosive Environment \_\_\_\_\_

Steel Sections: heavy \_\_\_\_\_ light \_\_\_\_\_ fasteners \_\_\_\_\_

Overall Appearance \_\_\_\_\_

Apparent Spangle/Heavily Weathered \_\_\_\_\_

Discoloration/Rust Staining \_\_\_\_\_

Silicon Steels \_\_\_\_\_

**FIG. X2.1 Case Study Report Sheet**



Condition of Paints \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Effect of Orientation/Elevation \_\_\_\_\_  
 \_\_\_\_\_

Factors Causing Localized Corrosion: chemical spills \_\_\_\_\_  
 fumes \_\_\_\_\_ high humidity \_\_\_\_\_ elevation \_\_\_\_\_  
 other \_\_\_\_\_

List of Photographs and Identification Numbers

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Remarks, Changes Since Previous Inspection

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## V. Coating Thickness Survey—Method A

### Procedure

1. One report per corrosive environment or position.
2. Selection based on section thickness, a minimum of three representative members of each light (bracing) and heavy (column beam).
3. At each location, a minimum of five measurements to determine the mean.

Project/Installation Name \_\_\_\_\_

Location \_\_\_\_\_

Survey Date \_\_\_\_\_/

name

firm

address

phone

Inspector \_\_\_\_\_

Site Contact \_\_\_\_\_

Corrosive Environment \_\_\_\_\_

Gage type \_\_\_\_\_  $\mu\text{m}/\text{mils}$  (circle one) Calibration Plates \_\_\_\_\_

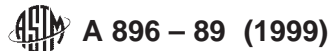
| Heavy Member Section/Location | Thickness Readings |       |       |       |       |       | Mean  |
|-------------------------------|--------------------|-------|-------|-------|-------|-------|-------|
| 1. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |
| 2. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |
| 3. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |
| <i>Light Member</i>           |                    |       |       |       |       |       |       |
| 1. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |
| 2. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |
| 3. _____                      | _____              | _____ | _____ | _____ | _____ | _____ | _____ |

Fasteners \_\_\_\_\_  
 \_\_\_\_\_

List of Photographs and Identification Numbers

\_\_\_\_\_  
 \_\_\_\_\_

FIG. X2.1 Case Study Report Sheet (continued)



Remarks \_\_\_\_\_

## VI. Coating Thickness Survey—Method B, Inspection Report (every inspection)

### Procedure

1. One report per corrosive environment with three reading areas for each.
2. 25 measurements in 5 by 5 grid, outside corners 50 by 50 mm square.
3. Mark test area for future; center punch outer square 75 by 75 mm.
4. List remarks, photograph, in comments (for general and specific test locations).

Project/Installation \_\_\_\_\_

Date \_\_\_\_\_ Inspection # \_\_\_\_\_

phone

Inspector \_\_\_\_\_

### Site Contact

Comments\_\_\_\_\_

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## VII. Coating Thickness Survey—Method B, Locations Description

Date\_\_\_\_\_ Project\_\_\_\_\_

| Location # | Project description, steel section, exact location and orientation, specific corrosive environment, draw site plan |
|------------|--|
|------------|--|

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1

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| Age Group | Total (%) | Male (%) | Female (%) | Male (%) | Female (%) |
|-----------|-----------|----------|------------|----------|------------|
| 18-24     | 15        | 10       | 20         | 10       | 20         |
| 25-34     | 25        | 15       | 35         | 15       | 35         |
| 35-44     | 35        | 25       | 45         | 25       | 45         |
| 45-54     | 25        | 15       | 35         | 15       | 35         |
| 55-64     | 15        | 10       | 20         | 10       | 20         |
| 65+       | 10        | 5        | 15         | 5        | 15         |

FIG. X2.1 Case Study Report Sheet (continued)



## VIII. Coating Thickness Survey—Method B, Readings

Date \_\_\_\_\_ Inspection # \_\_\_\_\_

Project \_\_\_\_\_

Inspector \_\_\_\_\_

Gage Type \_\_\_\_\_  $\mu\text{m}/\text{mils}$  Calibration Plate Type \_\_\_\_\_

| Readings   |       |       |               |       |       | Readings   |       |       |               |       |       |
|------------|-------|-------|---------------|-------|-------|------------|-------|-------|---------------|-------|-------|
| Location # | _____ | _____ | _____         | _____ | _____ | Location # | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
|            |       |       | $S_m90$ _____ | Mean  |       |            |       |       | $S_m90$ _____ | Mean  |       |
| Location # | _____ | _____ | _____         | _____ | _____ | Location # | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
|            |       |       | $S_m90$ _____ | Mean  |       |            |       |       | $S_m90$ _____ | Mean  |       |
| Location # | _____ | _____ | _____         | _____ | _____ | Location # | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
|            |       |       | $S_m90$ _____ | Mean  |       |            |       |       | $S_m90$ _____ | Mean  |       |
| Location # | _____ | _____ | _____         | _____ | _____ | Location # | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
| _____      | _____ | _____ | _____         | _____ | _____ | _____      | _____ | _____ | _____         | _____ | _____ |
|            |       |       | $S_m90$ _____ | Mean  |       |            |       |       | $S_m90$ _____ | Mean  |       |

 $S_m90$ \_\_\_\_\_Mean $S_m90$ \_\_\_\_\_Mean

FIG. X2.1 Case Study Report Sheet (continued)



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