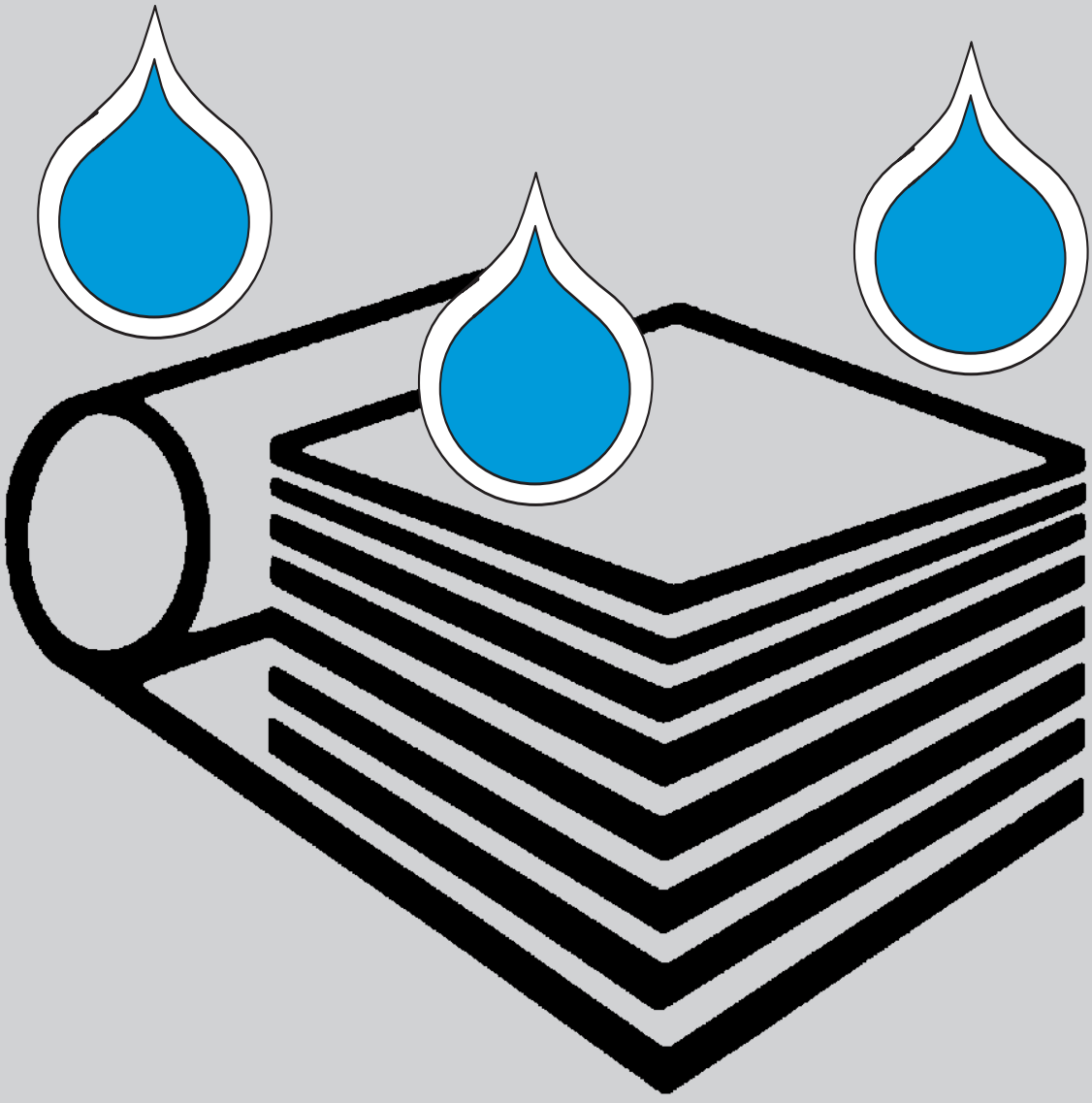
Guidelines for Minimizing Water Staining of Aluminum

The Aluminum Association
Incorporated



TR3

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The Aluminum Association, Inc. is the trade association for producers of primary aluminum, recyclers and semi-fabricated aluminum products, as well as suppliers to the industry. Based in Arlington, Virginia, with offices in Detroit, Michigan, the Association provides leadership to the industry through its programs and services which aim to enhance aluminum's position in a world of proliferating materials, increase its use as the "material of choice," remove impediments to its fullest use, and assist in achieving the industry's environmental, societal, and economic objectives. Member companies operate about 200 plants in the U.S and many conduct business worldwide.

The Aluminum Association

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1. Introduction

Aluminum is naturally attractive and resistant to corrosion. Unlike most other metals, it takes care of itself. When exposed to dry or moist air it combines with oxygen to form a tough, transparent, protective oxide coating. In the presence of moisture, aluminum will not rust as will steel, but under certain conditions aluminum will stain. Such stains are usually found objectionable for esthetic reasons; they have no significant effect on strength but may cause processing problems where additional surface finishing or fabrication is to be performed. Virtually all staining problems occur during shipping, handling, or storage. Some of the incorrect practices that result in water staining and ways to minimize or avoid the staining are discussed in this pamphlet. A summary of the measures to minimize water staining is provided in Appendix 1 and is reproduced as a handy wall chart, which is included with this pamphlet. Copies of the chart may be obtained from The Aluminum Association.

2. Causes of Water Stain

Aluminum and other metals can stain when water is trapped between wraps, sheets or other mating surfaces. If there is no air flow to remove the water, prolonged contact between the water and the metal causes a reaction between the two which results in water stain. Figures 1 and 2 show examples of water staining on aluminum coiled and flat sheet, respectively. There are two main sources of this water:

A. External Sources

Obvious sources are rain, snow and water leaks. Water coming in contact with the surface of the aluminum from sources such as a leaking tarp on a truck or a leaking roof in a storage area has the potential for causing water stain.

B. Moisture Condensation

This is the more complex of the two sources and therefore harder to understand and control. Air normally contains moisture in the form of invisible water vapor. Relative humidity, expressed as a percentage, provides a measure of the amount of water vapor actually in the air compared to the total amount of water vapor that the air can hold. As the temperature of air increases, its capacity to hold water vapor increases.

Dew point is the temperature at which water vapor from the air begins to condense and is affected by the relative humidity and temperature of the air. The dew point can be determined from a chart (see Table 1), based on simple measurements of air temperature and relative humidity. The type of instrument used to measure (and log) temperature and relative humidity is shown in Figure 3. The older style of thermometers containing mercury should not be used because mercury from broken thermometers can corrode aluminum and other metals. Some suppliers of these instruments are listed in Appendix 2.A.

Figure 1 – Water Stain on Coil

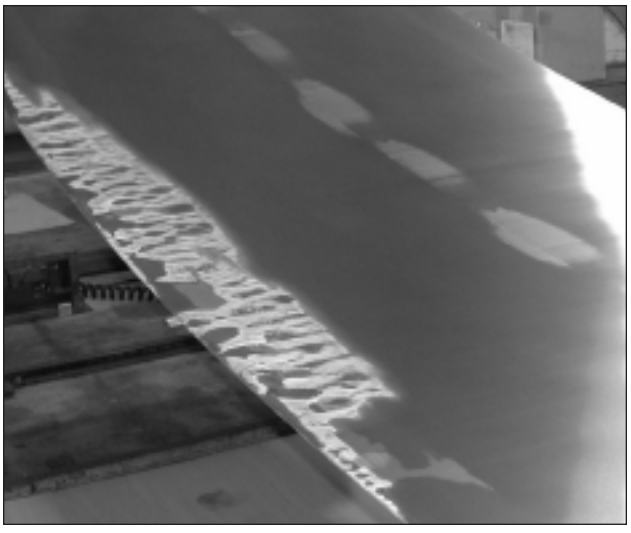

Figure 2 – Water Stain on Sheet

Figure 3 – Digital Instrument for Measuring Temperature & Humidity

Figure 4 – Condensation on Cold Aluminum Cans

Water vapor condenses on the surface of a metal if the temperature of the metal drops below the dew point of the surrounding air. A familiar example of condensation is the fogging of one's eyeglasses upon entering a warm room after being in the cold outdoors. Another common example is condensation on a cold beverage can as shown in Figure 4.
As mentioned before, when the temperature of aluminum drops below the dew point of air, water comes out of the air and deposits on the surface of the aluminum. The temperature of the aluminum can drop below the dew point of the air under the following circumstances:

1. ***During Storage:***
   When storing metal, it is not recommended to leave warehouse doors open especially during the spring and fall months, when there may be extreme differences in temperature between day and night. During the night, cold air enters and starts cooling the metal. During the day, if the temperature and humidity of the air increase rapidly, the dew point rises quickly. But, the temperature of the aluminum increases at a much slower rate; this sets up the condition where water begins to condense on the surface of the aluminum.

   Obviously this process is not limited to fall and spring months but may occur whenever there are large enough fluctuations in temperature and humidity.

2. ***During Loading:***
   Loading metal removed from a cool or cold storage area into a warm trailer or railroad car, on a humid day, can result in condensation on the aluminum. This can occur during any season of the year; however, for some areas it may be more pronounced in summer.

3. ***During Unloading-Moving Cold Metal Into Warm Storage:***
   Condensation at the unloading point is more likely to occur during the cooler months. The following example may help to clarify this point:

   Metal at 16°C (60°F) in a warehouse is loaded into a trailer and shipped. The metal is in transit for about two days. The outside temperature is - 1°C (30°F). Within a two-day transit period, the temperature of the metal gradually decreases to -1°C (30°F). When the aluminum reaches its destination, it is unloaded and moved directly into a warehouse where the temperature is 16°C (60°F) and the relative humidity is 50%. From Table 1, the dew point of the air is 5°C (41°F). Since the temperature of the aluminum is now lower than the dew point of the air, conditions are ideal for water to condense on the surfaces such as the edges of stacked sheet or coils. The condensed moisture can enter between the sheets and wraps by capillary action and may produce water stain.

Table 1: Dew Point Calculator

Air Temperature in Degrees Celsius

Air Temp °C	% Relative Humidity																		
	100	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**
43	43	42	41	40	39	38	37	35	34	32	31	29	27	24	22	18	16	11	5
41	41	39	38	37	36	35	34	33	32	29	28	27	24	22	19	17	13	8	3
38	38	37	36	35	34	33	32	30	29	27	26	24	22	19	17	14	11	7	0
35	35	34	33	32	31	30	29	27	26	24	23	21	19	17	15	12	9	4	0
32	32	31	31	29	28	27	26	24	23	22	20	18	17	15	12	9	6	2	0
29	29	28	27	27	26	24	23	22	21	19	18	16	14	12	10	7	3	0	
27	27	26	25	24	23	22	21	19	18	17	15	13	12	10	7	4	2	0	
24	24	23	22	21	20	19	18	17	16	14	13	11	9	7	5	2	0		
21	21	20	19	18	17	16	15	14	13	12	10	8	7	4	3	0			
18	18	17	17	16	15	14	13	12	10	9	7	6	4	2	0				
16	16	14	14	13	12	11	10	9	7	6	5	3	2	0					
13	13	12	11	10	9	8	7	6	4	3	2	1	0						
10	10	9	8	7	7	6	4	3	2	1	0								
7	7	6	6	4	4	3	2	1	0										
4	4	4	3	2	1	0													
2	2	1	0																
0	0																		

Air Temperature in Degrees Fahrenheit

Air Temp °F	% Relative Humidity																		
	100	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**
110	110	108	106	104	102	100	98	95	93	90	87	84	80	76	72	65	60	51	41
105	105	103	101	99	97	95	93	91	88	85	83	80	76	72	67	62	55	47	37
100	100	99	97	95	93	91	89	86	84	81	78	75	71	67	63	58	52	44	32
95	95	93	92	90	88	86	84	81	79	76	73	70	67	63	59	54	48	40	32
90	90	88	87	85	83	81	79	76	74	71	68	65	62	59	54	49	43	36	32
85	85	83	81	80	78	76	74	72	69	67	64	61	58	54	50	45	38	32	
80	80	78	77	75	73	71	69	67	65	62	59	56	53	50	45	40	35	32	
75	75	73	72	70	68	66	64	62	60	58	55	52	49	45	41	36	32		
70	70	68	67	65	63	61	59	57	55	53	50	47	44	40	37	32			
65	65	63	62	60	59	57	55	53	50	48	45	42	40	36	32				
60	60	58	57	55	53	52	50	48	45	43	41	38	35	32					
55	55	53	52	50	49	47	45	43	40	38	36	33	32						
50	50	48	46	45	44	42	40	38	36	34	32								
45	45	43	42	40	39	37	35	33	32										
40	40	39	37	35	34	32													
35	35	34	32																
32	32																		

Example: Read the air temperature in the left hand column and the humidity at the top of the above chart. If the temperature of the storage area is 13°C (55°F) and the relative humidity is 60%, the intersection of the two shows the dew point of the area to be 4°C (40°F). If the metal coming in is below 4°C (40°F), water will condense on the metal.

3. Packaging

Packaged aluminum coils, flat sheet, and plate should be wrapped with various papers, plastic films, or laminates that provide reasonable protection against moisture penetration during shipment and storage. Coils should have caps on the ends for either vertical or horizontal stacking and shipment. When using a shrink wrap, it should envelop the entire package to ensure any condensation has an opportunity to run off and not penetrate the package. However, it should be recognized that any such packaging may not be air-tight, and changes in temperature or humidity may still result in condensation on the aluminum surfaces. Packaged aluminum, even if protected with "waterproof" materials, should not be stored outdoors.

Wrapping materials should be left intact (and repaired if torn) until the aluminum is used. If moisture is condensing on the packaging as shown in Figure 5, the moisture should be removed but not the packaging. If the packaging is soaked or if the aluminum is wet, then the procedures mentioned on page 9 should be followed.

When surface quality is critical, aluminum flat sheets and plate should be additionally interleaved with special paper, foam sheets or other materials to protect the surfaces against abrasion. Even though some interleaving papers contain an additive to inhibit water staining, the normal precautions during transit, handling, and storage should be followed. It is very important that the coil or sheet metal package is securely attached to the skid to eliminate any possibility of movement which can tear or otherwise compromise integrity of the packaging during shipping. Use of desiccants is not recommended due to rapid overload conditions that can occur during long routes and the very large quantity of moisture that can accumulate on cold surfaces.

Figure 5 – Moisture condensation on packaged metal

4. Inspection Procedures

Because there is normally a time limit on carrier claims, incoming inspection becomes a vital part of the receiving process. Without incoming inspection the receiver cannot know what the condition of the metal is and how susceptible it may be to water staining. Without this knowledge the necessary steps to prevent the staining cannot be taken:

A. If any physical or water damage is found on the skids, packaging or the metal, this should be noted on the receiving papers. Any package that is torn and exhibits a significant water accumulation should be considered suspect and scheduled for additional review and potentially targeted for immediate usage subject to production schedules and constraints. If possible the coil or flat sheet should be inspected and reoiled via recoiling or restacking operation. If it has been recorded, the temperature/humidity data should be transmitted to the shipping point to assess particular conditions, track trends and develop improved routing, packaging or mode of transportation.

B. Water vapor will condense on the surface of the metal if its temperature is lower than the dew point of the air in the storage area. (See Figure 6) It is important, therefore, to check the temperature of a few coils in every shipment and compare that temperature to the dew point of the storage area. (Refer to section 5. A.3)

Figure 6 – Heavy Water Condensation on a Coil

The temperature of the aluminum can be easily measured by using a probe thermometer, as shown in Figure 7, or by cutting a 6 inch by 6 inch flap in the wrapping paper and placing a contact, dial-type thermometer on the surface of the aluminum, as shown in Figure 8. After recording the temperature, it is important to reseal the package by replacing and taping the flap. If not repaired, condensate could run down the inside of the wrap and result in water stain.

C. An alternative method of identifying coils exposed to moisture is through the use of moisture tags (a.k.a. "Weeping Eyes"). See Appendix 2.B. for a list of suppliers. These tags, made of moisture absorbent material, can identify exposure to moisture by changes to the shape and/or color of the tag depending upon the specific indicator used. Figure 9 shows a new tag while Figure 10 shows the effect of exposure to a water mist. If the tag shows exposure to moisture, follow the directions in Appendix 1.

Figure 7 – Probe Thermometer

Figure 9 – Unexposed Moisture Label

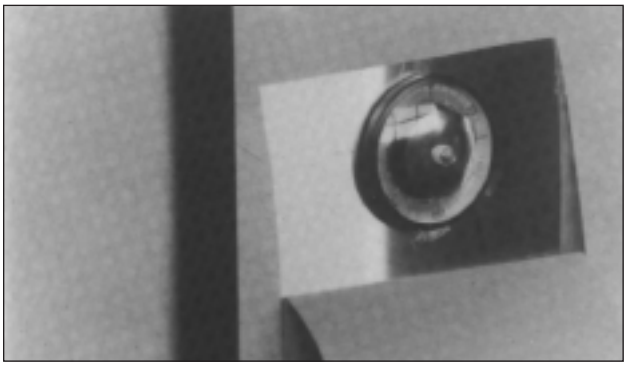

Figure 8 – Contact thermometer

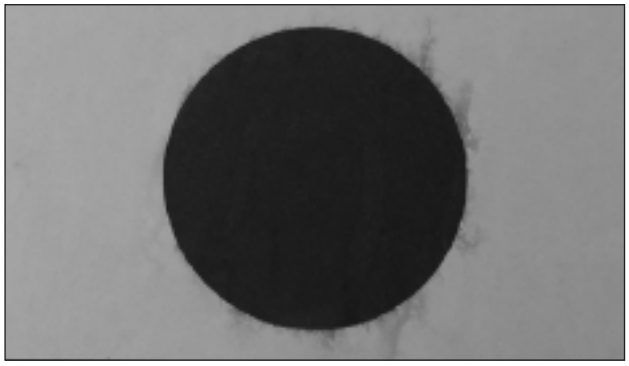

Figure 10 – Moisture Label after Water Mist Exposure

5. Prevention

There are three methods of preventing water stain:

A. Prevent water in any form from coming into contact with the metal

B. If water is already in contact with the metal, remove it

C. Consider precautionary measures to minimize water staining

A. Prevent water in any form from coming into contact with the metal

To prevent the water from getting between wraps, sheets or other mating surfaces, it is critical to prevent the temperature of the metal from getting below the dew point of the surrounding air.

1. **STORAGE:**
   Intact packages should be stored in a dry area with good ventilation to ensure stabilization of the package. Temperature and humidity variations within the warehouse should be kept to a minimum by keeping outside doors closed. For surface critical products, air conditioned warehouses with limited access are preferred. If use of an air conditioned warehouse is not feasible, packages should be periodically inspected to verify that storage conditions have not deteriorated. Stock should be rotated as quickly as possible.

   It is also advisable to have forced circulation heaters in the storage area to maintain the temperature of the metal above the dew point of the ambient storage environment. Without fans to

distribute heat, storing aluminum near walls, doors, windows, and other cooler areas may provide the conditions for condensation.

Neither packaged nor bare aluminum should be stored outdoors unless water stain is not detrimental for the end use.

2. SHIPMENTS:

For surface critical products it is important to minimize day/night temperature cycling during typical storage and/or transit, and the preferred method is to use insulated trucks or rail cars. It is essential that long layovers at truck and rail depots are minimized. If this mode is not feasible due to metal shape or economic considerations, and flat bed trucks are used, it is very important that the load is completely covered using high integrity tarpaulin. The truck bed and tarpaulin should be dry prior to loading and securing the load. Ensure that coils and sheet metal are securely attached to their skids, and that the skids are properly secured to prevent movement and damage to the packaging. To help assess the history of the shipment it is recommended that portable, temperature/humidity recorders be incorporated in the load. Quick review of the temperature/humidity data will allow an assessment of the potential risk of water stain and will facilitate a decision on any need for potential salvage of the metal received.
It is important to:

a. Minimize in-transit times and temperature cycling.
b. Use insulated or heated trailers in the winter whenever possible.
c. Check tarps on open-top trucks to make sure there are no holes. The carrier should re-tarp the truck after each intermediate delivery.
d. Use portable, temperature/humidity recorders for critical products.

3. RECEIVING:

If during the incoming inspection process the temperature of the metal is found to be below the dew point of the air in the storage area, the following steps should be taken:

a. Do not move cold metal into a warm storage area (remember the fogging of eye-glasses). Allow the metal to warm up slowly. This can be done by placing the unopened package in a cooler area, free from drafts.
b. Check the condition of the metal every few hours to make sure that no water has condensed on the surface.
c. *Communication is essential. Any evidence of improper shipping mode, damaged packaging, and any obvious water staining should be reviewed with the metal producer.*

B. If water is already in contact with the metal, remove it

Steps should be taken to remove this water before it stains the aluminum.

Unfortunately, there is no easy way to remove the water. Contacting the supplier may be helpful. The supplier is generally familiar with prevention techniques and can provide assistance. Some possible procedures that might be recommended are:

1. If at all possible, process the aluminum immediately and dry it as it is being used. *This is the only sure way of getting rid of the water.*
2. If in coil form, unskid and unpackage the aluminum, lay it on its side and use fans to blow air around it-hot air if possible.

C. Consider precautionary measures to minimize water staining

If water stained metal is a major recurring problem, a way of minimizing the problem would be to coat the aluminum with a water stain preventative. Most aluminum suppliers have such preventatives but hesitate to use them without prior knowledge of a customer's operations to ensure that there are no compatibility problems with the end use application and/or local environmental regulations. If requested by the purchaser, synthetic (water free) oils, which provide a high level of protection, may be applied by the aluminum producer during their fabrication/processing sequence. However, some aluminum suppliers may not be able to coat all items. A list of suppliers of water stain preventatives is shown as Appendix 2.C.

6. Conclusion

The Aluminum Association hopes this pamphlet has provided a better understanding of water stain, its causes, and some of the steps that can be taken to prevent it.

Some of the recommended procedures may require added efforts, but the value of the aluminum and assured production schedules may justify the suggested precautions.

Appendix 1: Aluminum Water Stain Prevention

A. When you receive metal:

1. Check for wetness.

a. Is the metal wet? Is the wrapping paper puckered up or wet?
b. *If it is wet, note it on all copies of the receiving papers.*
c. Inform the Purchasing Department or Quality Control immediately.
d. Remove the water or, if possible, immediately use the metal.

2. Check to see if the metal feels cold. If it does:

a. Tell your supervisor immediately.
b. Leave the metal in a cool indoor area away from drafts to allow it to warm up slowly. (If this is not done, and the metal is put in a heated warehouse immediately, it may sweat and get water stained.)
c. After the metal is reasonably warm (about a day later), move it to the warehouse.

B. When you move metal between areas:

Check to see if the temperature in the area the metal will be taken to is higher than the temperature in the area the metal is coming from.

If the difference is more than 11°C (20°F):

a. Only move as much metal as will be used immediately.
b. Tell your supervisor.
c. Leave the remainder of the metal where it is until ready for use.

Appendix 2: Suppliers

A. Measurement Instruments

The Thermometers and hygrometers for measurement of air temperature and relative humidity and thermometers for measurement of metal temperature may be obtained from:

Cole-Parmer Instrument Company
625 East Bunker Court
Vernon Hills, Illinois 60061-1844
1-(800) 323-4340
1-(847) 247-2929 - Fax
info@coleparmer.com - E-mail
www.coleparmer.com

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
1-(800) 766-7000
1-(800) 926-1166 - Fax
www.fisherscientific.com

McMaster-Carr Company
P.O. Box 54960
Los Angeles, CA 90054-0960
1-(562) 692-5911
1-(562) 695-2323 - Fax
la.sales@mcmaster.com
www.mcmaster.com

Tech Instrumentation, Inc.
160 W Kiowa Ave
PO Box 2029
Elizabeth, CO 80107
1-(800) 390-0004
1-(303) 841-7567
1-(303) 840-8568 - Fax
sales@techinstrument.com - E-mail
www.techinstrument.com

Thomas Scientific
P.O. Box 99
Swedesboro, NJ 08085
1-(856) 467-2000 - General
1-(800) 345-2100 - Customer Service
1-(856) 467-3087 - Fax (Worldwide)
1-(800) 345-5232 - Fax (US Only)
value@thomassci.com - E-mail
www.thomassci.com

VWR International LLC
1310 Goshen Parkway
West Chester, PA 19380
1-(800) 932-5000
1-(610) 431-1700
1-(610) 431-9174 - Fax
www.vwr.com

B. Moisture Indicating Labels

BGR Inc.
6392 Gano Road
West Chester, OH 45069
1-(800) 628-9195
1-(513) 755-7100
1-(513) 755-7855 - Fax
www.bgrinc.com

ITW Metals Group
1-(800) 862-7997
1-(630) 268-9919 - Fax
sfisher@fleetsig.com - E-mail
www.fleetsig.com

C. Water Stain Preventatives

CRC Industries, Inc.
885 Louis Drive
Warminster, PA 18974-2869
1-(800) 556 - 5074
1-(215) 674-4300
1-(215) 674-2196 - Fax
crcwebmaster@crcindustries.com - E-mail
www.crcindustries.com

Henkel Surface Technologies
32100 Stephenson Highway
Madison Heights, MI 48071
1-(800) 521-6895
1-(248) 583-9300
1-(248) 583-2976 - Fax
www.finishing.com/Products/henkel

Quaker Chemical Corp.
World Headquarters
One Quaker Park
910 Hector St.
Conshohocken, PA 19428-0809
1-(610) 832-4000
www.quakerchem.com

The lists in these appendices are included only as a convenience. No attempt has been made by the Association to evaluate the effectiveness of the products, nor does listing here constitute an endorsement. The lists are not to be considered all-inclusive, but do represent all such suppliers known to the Association at the time of publication of this document. Some of the companies listed have additional United States sales offices or outlets where the products can be purchased. Other suppliers will be added as they become known to us and their names will be made available in response to inquiries and at republication of this document. The responsibility for the selection, determination of suitability, and proper use of the products is left to the user.

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Aluminum Press Forming Processes (Video)
SKU: AV-PFP-792606

Equipment for the Slitting Line (Video)
SKU: AV-ESL-792609

Guidelines for In-Plant Handling of Aluminum Plate, Flat Sheet and Coil, 2006
SKU: TR-7-792602

Guidelines for Minimizing Water Staining of Aluminum, 2009
SKU: TR-3-792601

Leveling and Cutting-to-Length of Aluminum Coiled Sheet (Video)
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Rolling Aluminum: From the Mine through the Mill, 2008 (DVD)
SKU: AV-RAMDVD-792617

Rolling Aluminum: From the Mine through the Mill, 2008
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Slitter Tooling and Set-Up (Video)
SKU: AV-STSU-792608

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SKU: AV-TTACS-792607

Visual Quality Characteristics of Aluminum Sheet and Plate, 2009
SKU: QCA-1-792615

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