Steel Coalition

Steel Coalition Lubricant Task Group

Final Report

May 14, 2002

American Iron
and Steel Institute

NATIONAL
COIL COATING
ASSOCIATION

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METAL BUILDING MANUFACTURERS ASSOCIATION

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Metal Construction Association

STEEL JOIST INSTITUTE
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Preface

This report is the result of the work of the Lubricant Task Group of the Steel Coalition. The Steel Coalition is comprised of the American Iron and Steel Institute (AISI), the Metal Building Manufacturers Association (MBMA), the Metal Construction Association (MCA), the National Coil Coaters Association (NCCA), the Steel Deck Institute (SDI), and the Steel Joist Institute (SJI). Individual members of the Task Group were:

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This report provides General Recommendations in Section 4 and Specific Recommendations in Section 5 for both decking and roofing products. It is pointed out in the report that the success of these recommendations on achieving the objective of eliminating the presence of visible liquid lubricants and minimizing dry residues that might increase the slipping hazard is highly dependent on individual manufacturing operations. Each manufacturer will have to establish their own set of parameters that best address the roll forming problems. This is particularly important in the determination of safety and environmental impact of highly evaporative lubricants in complying with local and state regulations.

It is the goal of the Steel Coalition that deck and roofing manufacturers evaluate these recommendations within their own facilities to determine what is effective and what is not effective in obtaining the objective. A period of two years is available for this evaluation before final recommendations are presented to OSHA. The Steel Coalition will monitor this process to make sure the evaluations are proceeding and that the knowledge gained is shared within the industry.

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1.0 INTRODUCTION

1.1 Background

The Negotiated Rulemaking Act of 1990 was adopted to involve all stakeholders in the OSHA rulemaking process. OSHA utilized this rulemaking process to revise the Subpart R regulations governing steel erection. Based on industry accident statistics, OSHA deemed it necessary to incorporate rules to mitigate injuries resulting from slips and falls in the erection of metal roofs and decks. As part of this cooperative effort, the Steel Coalition was formed to obtain input from the rulemaking body, labor, contractors, and manufacturers to develop recommendations that would result in meaningful improvements to worker safety.

In 1997 the Steel Coalition commissioned Dr. George Sotter, a recognized expert in slip and human traction, to conduct extensive investigations into the potential causes for slipping accidents in the construction industry. His report, "Research Toward the Rapid Minimization of Slipping Incidents on Construction Site Steel Products", was issued on June 7, 1998. This investigation documents many potential contributory factors to slip-related injuries in the construction industry. In his recommendations, he identified 19 different points for consideration by the associations that comprised OSHA/SENRAC and the Steel Coalition. The Steel Coalition Lubricant Task Group was established to investigate one of these recommendations -- to reduce or eliminate the presence of lubricants on decking and roofing products as-delivered to the jobsite. This report summarizes the results to-date of several technical investigations conducted by the Steel Coalition to accomplish that goal.

1.2 Metal Roofing and Metal Decking

Metal decking and metal roofing are differentiated by end use. Metal roofing is typically used for exterior applications while metal deck is an interior product that is covered by other materials. OSHA broadly defines decking to include both metal roofing and metal decking, but a distinction is needed because of the difference in the products as further explained in this section.

1.2.1 Metal Decking

Metal deck is used as a temporary walking or work surface. Metal deck supports floors or roofs and is typically installed in a nearly horizontal plane. Floor deck is a "stay in place" form for concrete. Some floor deck also interlocks with the concrete to produce composite deck that provides significantly greater strength and stiffness than the deck alone. The typical roof deck system is insulated and covered by a weather resistant membrane.

Most decking is rolled from mill-supplied coils of either hot dipped galvanized or cold rolled steel. Galvanized deck is often supplied unpainted. The deck manufacturer can provide painted product using either galvanized or cold rolled steel base material. The paint is applied to either one or both surfaces. Some cold rolled deck is provided phosphatized (chemically treated) and the uncoated steel becomes the walking surface. Decking is fabricated into the final configuration using multiple-stand roll forming mills. It is during this process that lubricants may be used to minimize pick-off or galling of the metallic coating. Such marring can result in off-standard product. Lubricants also help achieve the desired profile shape. Painted deck normally does not require additional lubricants during the roll forming operation.

1.2.2 Metal Roofing

Metal roofing panels are usually installed with a slope. The degree of slope may range from virtually horizontal (1/4 in 12) to steep slopes (4 in 12 or steeper). Metal roof panels are intended as the finished weathering surface of a structure. Roofing panels are produced from galvanized sheet, Galvalume® sheet, painted galvanized sheet, painted Galvalume® sheet, and acrylic-coated Galvalume® sheet. Other kinds of metal roofing are also used in the industry. However, galvanized sheet and Galvalume® steel sheet represent the vast majority of material used.

Panels for metal roofing are formed from flat coils similar to those used for metal deck panels. Galvalume® sheet and galvanized roof panels must be protected from pick-off just like the galvanized steel deck panels described above. Lubricants are used to prevent such pick-off or galling during the roll forming operation. The paint used on painted roof panels is formulated to prevent pick-off and metal marking without the use of lubricants during the forming operation. Painted roofing panels normally do not require the addition of lubricants during roll forming. Acrylic-coated Galvalume® sheet is also designed to be roll-formed dry, without the use of lubricants.

1.2.3 Corrosion Protection

In addition to preventing galling of the bare galvanized steel or bare Galvalume® sheet, some lubricants also provide corrosion protection of the bare metal during shipment and storage. This type of lubricant is typically applied at the metal producer and may be augmented with additional lubrication applied at the panel producer (roll former). Acrylic-coated Galvalume® sheet, as well as the painted products, provides this corrosion resistance without the application of any lubricants or additional protectants.

2.0 RESEARCH PROGRAM

2.1 Objectives

The Lubricant Task Group has undertaken various evaluations to establish the properties of the forming and corrosion protection lubricants now used in the industry. Samples of the lubricants widely used were obtained and evaluated.

Under the direction of the Lubricant Task Group, research on the following topics was conducted to establish generalized properties of these lubricants.

1) Conduct evaporation studies to group lubricants with similar properties. Evaluations of evaporation rates and composition were made to establish these groupings.

2) Conduct user survey to determine which metals are used by the various members and the experience that these members have with forming lubricants.

3) Conduct formability testing on representative examples of the different lubricant groups. This testing focuses on the ability of these lubricants to prevent metal pick-off or galling.

4) Conduct drying tests to determine how the various lubricants evaporate in a production environment.

5) Conduct wet storage testing to determine the contribution of the lubricant to the storage staining resistance of bare galvanized steel and bare Galvalume® sheet.

2.2 Research Findings

2.2.1 Evaporation Studies

2.2.1.1 Evaporation Test Description

Sunderman Laboratories conducted studies on evaporation rates and chemical composition of 19 different lubricants. The list of lubricants was obtained by surveying the industry, thereby representing those commercially used. These evaluations were conducted to answer several specific questions regarding the lubricants.

This investigation was sponsored by the Steel Coalition. Lubricants used in the industry to lubricate metallic coated steel deck and roof panels prior to and during the forming operation were evaluated. These lubricants are used by the manufacturers to prevent metal pick-off and galling of the metallic coated steel sheet. In some cases these lubricants also provide resistance to corrosion during shipment and storage.

To determine the evaporation characteristics of the lubricants, the evaporation over time under various atmospheric conditions was observed. The weight loss of these lubricants over time after they were applied to metal panels was recorded. The conditions of study included room temperature (75°F), elevated temperature (100°F), cold temperature (46°F), and high humidity at room temperature (greater than 80% RH, and 75°F). The results of these evaluations were presented in graphical form to show the relative evaporation characteristics of the different lubricants under the different environmental conditions. Results were presented both as the actual weight loss over time and as the percent weight loss over time under the established conditions.

Other tests were conducted to determine critical properties of the lubricants that are relevant to the use of these materials. These tests included: determination of the weight percent volatile components of the lubricants, effect of high velocity air drying, water solubility of lubricant residue, Infrared Spectroscopic analysis, X-Ray analysis, and determination of the evaporation rate of the lubricants according to ASTM D3539, "Standard Test Methods for Evaporation Rates of Volatile Liquids by Shell Thin-Film Evaporometer".

2.2.1.2 Lubricant Classifications

Based on the results of these evaluations, several families were established into which all of the lubricants could be grouped. These groupings represent similarities in the properties of the lubricants and allow for generalizations to be made about each group.

The groupings that were established are as follows:

> GROUP A - This group consists of lubricants that are 100% volatile organic solvents. After evaporation, no measurable residual material remains on the processed sheet. Complete evaporation is typically obtained in less than eight minutes under ambient conditions when the material is applied at a rate of approximately 9,000 square feet per gallon. These lubricants are all aliphatic hydrocarbons. They do not contain any corrosion inhibitors.
>
> GROUP B - This group consists of organic solvent-based lubricants that are greater than 95% volatile. These lubricants consist of aliphatic hydrocarbon solvents with less than 5% of added compounds. According to the manufacturer's literature, these additions contribute to and improve the lubricating properties of the lubricant. The amount of residual material left on the lubricated sheet depends on the application rate. However, this amount is less than 5% of the total amount applied. The evaporation rate of these materials is similar to those lubricants in Group 'A'.
>
> GROUP C - The lubricants in this group contain some evaporable solvent and significant quantities of residual material. The manufacturer's literature for these lubricants indicates that they contain non-evaporating, corrosion inhibiting compounds. This group is intended to provide lubrication during forming and also corrosion inhibition during storage. One of these lubricants is referred to as slushing oil. This material is 99% non-volatile. The other two materials referred to as vanishing oils, are 53% non-volatile and 22% non-volatile. These lubricants will only partially evaporate in the field. The amount of lubricant left on the sheet depends on the application rate. When applied

at rates in excess of the recommended rates, these lubricants might be noticeable in the field.

GROUP D - There is only one lubricant in this group. This lubricant is water-soluble (not emulsifiable) and does not contain any 'oils'. The amount of residual material left by this product is small and it is not 'oily'. This lubricant will go back into solution when rewetted.

GROUP E - This group consists of only one lubricant. This lubricant is an emulsion of oil in water. A corrosion inhibitor is incorporated in the residual oil. The residual material left on a sheet is 'oily' and can be re-emulsified when exposed to water in the field. The quantity of residual material is similar to that of Group B.

Code numbers were used for all of the lubricants tested in this study to maintain confidentiality.

The results showed that some lubricants left no measurable residue on the sheet and one left as much as 98% residue on the sheet. Nine lubricants did not leave any measurable residue on the sheet (Group A). Seven of the lubricants (Group B, Group D, and Group E) left less than 5% residue on the sheet. Three lubricants tested left more than 5% residue (Group C).

The three organic solvent-based lubricants with greater than 5% residue all contained rust inhibitors and are intended to protect the sheet during transit and storage.

The water solubility of the residue left on the sheet was evaluated. Nine lubricants had no measurable residue (Group A). The residue of the five organic solvent-based lubricants with residues did not show any water solubility (Group B). The residue of one of the lubricants from Group C with residue in excess of 5%, exhibited 100% solubility in water. The residues from the other lubricants in Group C are insoluble in water. The water-soluble lubricant (Group D) re-dissolved in this test. The water emulsifiable lubricant (Group E) re-emulsified in the water.

Test results indicate that the most critical aspect of the evaporation rate is the airflow rate over the panel face. Evaporation rates at low airflow showed some variation due to temperature and humidity. However, the fastest evaporation rates were observed at high airflow rates. Air temperature variation at high airflow rates had only a small effect on the evaporation rate.

2.2.1.3 Conclusions of Evaporation Testing

The objectives of the research program directed by the Lubricant Task Group required that certain specific questions be answered. After reviewing all of the test data, the following answers to the questions were provided.

- ***How rapidly do vanishing oils and other lubricants evaporate and what are the contributing factors?***

To answer this question it is best to consider the groupings of lubricant as developed in this research.

Seven of the lubricants studied and identified as Group A are 100% volatile. They will totally evaporate from a metal surface in a short time under normal conditions. Under the test conditions, that rate was between two and fifteen minutes, depending on how much material was first applied. There would be no residue left from these lubricant on the metal panel during the erection process.

Five lubricants identified as Group B are similar to those in Group A. The only difference is that these lubricants contain small amounts of additives (less than 5%) that are incorporated to improve the lubricant for specific end uses. This group of materials will evaporate in two to fifteen minutes under our test conditions. A maximum of 5% of the originally applied lubricant will remain after evaporation of the volatile portion. The residues on panels treated with these lubricants were difficult to detect by visual and tactile examination.

The temperature of the environment has a small effect on the evaporation rate of these lubricants. Air movement across the panel face, however, significantly affects the evaporation rates of Group A and Group B lubricants. When air is blown across the panel face the time to complete evaporation is significantly reduced. The temperature of the blowing air is not as significant as the quantity of air.

Relative humidity of up to 90% had no significant effect on the evaporation rates of Group A and Group B lubricants.

The water-soluble lubricant, Group D, and the water emulsifiable oil, Group E, have evaporation rates similar to water. They are slower evaporating than the solvents of Group A and Group B. The evaporation rates of these lubricants are significantly affected by the relative humidity. As the relative humidity increases the evaporation rate decreases.

Compared to the other groups, the three lubricants in Group C have relatively large amounts of residual material. A portion of these lubricants will evaporate. However, the rate is slow. The same factors that affect Group A and Group B lubricants affect evaporation of the solvent portions of these lubricants. After long exposure time, these lubricants still show an oily residue on the surface of the sheet. The quantity of residual material and consequently the ease of detection are dependent on the application rate. These products are designed to provide corrosion protection to the metal sheet.

- ***After the surface is dry and the lubricant has evaporated, is there a quantifiable residue and what is the chemical type and amount?***

Seven of the lubricants (Group A) studied are 100% volatile. They evaporate from a metal surface in a short time under normal conditions. There is no measurable residual material left on the panel surface. The surface appearance is the same after evaporation as it was before application of the lubricant.

Five lubricants (Group B) are similar to those in Group A, except that they contain up to 5% of non-volatile additives. Based on infrared spectroscopy, the residuals appear to be primarily carboxylic acid esters. Some samples also contain chlorine, which may indicate a chlorinated saturated hydrocarbon, and some samples contain a small amount of calcium and sulfur indicating the presence of a rust inhibitor. The residual materials from lubricants in this group would be difficult to detect in the field.

The water-soluble lubricant (Group D) has less than 3% of non-volatile material. The residual material is a complex mixture containing amines such as triethanol amine and possibly some high molecular weight alcohols. X-ray analysis shows the presence of a number of heavy elements. Detailed identification of the components is beyond the scope of this project. The residual material would be difficult to detect in the field.

The water emulsifiable lubricant (Group E) has a residue of less than 2%. Based on infrared spectroscopy and X-ray analysis the residue contains oils and rust inhibitors. The amount of residue is small and would be difficult to detect in the field.

The three lubricants in Group C have relatively large amounts of residual material. These residues are high molecular weight hydrocarbons (oils) and rust inhibitors. When used as forming lubricants they would remain on the panels until they are delivered to the field and erected. If these lubricants are applied at levels higher than the manufacturer recommended levels they could be detectable on panels in the field as an oily film.

- ***If a residue exists, is it reactivated by normal exposure to things such as rain, dew, and surface temperatures in the range of -30°F to 200°F? Does this residue go into solution or suspension? If it goes into solution or suspension, does it resettle to repeat the process?***

Of those lubricants that had residual non-volatile materials, three were soluble in water. A logical inference is that the lubricants would also be dissolved by rain or dew. Once the residue is in solution it will move wherever the water goes. When the water evaporates it will redeposit in that spot.

- ***Can the lubricants be grouped into a family of lubricants? Can ranges be established for the physical performance properties and chemical composition of these families?***

The lubricants have been grouped into families. These groups are explained in detail at the beginning of this section. By reviewing the MSD Sheet supplied with a forming lubricant one can generally determine which group the lubricant will probably fall. However, since the MSDS is intended as a safety notification, it does not always adequately describe the chemical composition of these lubricants for classification. General guidelines are as follows:

Group A will be described as 100% volatile hydrocarbon solvent usually an aliphatic hydrocarbon.

Group B is described as 95 % to 99% volatile hydrocarbon solvent. The non-volatile portion is often not specified because it is a material with no significant potential health effects.

Group C materials are described as less than 95% volatile hydrocarbon solvent content. They often contain a corrosion inhibitor such as calcium sulfonate.

Group D is water-soluble and contains no hydrocarbon oils.

Group E is a water dispersible oil containing surfactants for dispersion of the oil in water.

2.2.2 Survey of Coil Ordering Practices and Rolling Lubricant Application

2.2.2.1 Survey Description

This survey was conducted to determine the normal practices of the member companies. A total of 26 member companies responded to the survey. This included both deck manufacturers and roofing panel manufacturers.

2.2.2.2 Conclusions of Survey

Conclusions reached from analyzing the information are as follows:

- Of all of the respondents, 42% said that they have already ordered ‘Dry’. The majority of orders for ‘Dry’ material are for galvanized sheet.

- Only 9% of those who ordered ‘Dry’ material experienced coil storage problems to the extent that they stopped ordering ’Dry.’

Based on information provided by those manufacturers who order ‘dry’, the following information was obtained:

- It is suggested that the maximum storage on the plant floor before use be six months.

- Median time to storage problems is about 3-1/2 months for Galvanized steel and Passivated coils. (Less data but Galvalume® steel coils had about the same interval.)

- The least time to storage problems was 2 to 3 months for “passivated” product and 1 month for “non passivated” product.

- Most manufacturers (92%) are already using highly evaporative rolling compounds at their lines.

- Most manufacturers ordering, “Dry” and using highly evaporative rolling compounds do not experience bundle storage problems – 74% say never, 100% say rarely.

2.2.3 Wet Storage Stain Resistance (Stack Tests)

2.2.3.1 Stack Test Description

Galvanized steel and Galvalume® sheet are subject to wet storage staining under certain environmental conditions if they are not properly protected. Storage stain manifests itself as white rust on galvanized steel and as black storage stain on Galvalume® sheet. In the industry, two different methods are used to mitigate storage staining. The first method is to chemically treat the surface of the galvanized steel or Galvalume® sheet to chemically inhibit the corrosion process. The second method of mitigating storage corrosion is to use protective lubricants. A study was conducted to determine the relative efficacy of the various lubricants under consideration in preventing the storage stain.

To simulate the aggressive storage conditions, which result in storage staining, panels are tightly stacked together and placed in an environment with high humidity and high temperature. This testing is normally referred to as stack testing. Testing was conducted on 6 different lubricants, which represent the spectrum of lubricant types now used in the industry. These lubricant groups are those described in the Sunderman Laboratories report dated June 26, 2000. Materials used in the evaluation are summarized in Tables 2.2.1 and 2.2.2.

Table 2.2.1 Substrates Evaluated

Substrate	Symbol
Chemically Treated Hot Dipped Galvanized Steel	CTHDG
Non Chemically Treated Hot Dipped Galvanized Steel	NCTHDG
Chemically Treated Galvalume® Coated Steel	CTGL

Table 2.2.2 Evaporative Compounds Evaluated

Test Sample	Code	Type	Lubricant Group
1	SLS-12	100% volatile aliphatic hydrocarbons only	A
2	SLS-29	Water Based, contains Aliphatic hydrocarbons and Amines	D
3	SLS-43	100% volatile aliphatic hydrocarbons only	A
4	SLS-45	100% volatile aliphatic hydrocarbons only	A
5	SLS-50	Contains long chain carboxylic acid esters	B
6	SLS-54	Contains long chain aliphatic hydrocarbons with some branching	C
7	None	Control, no lubricant applied	None

2.2.3.2 Observations on Chemically Treated Hot Dipped Galvanized Steel

After 6 weeks exposure to the high temperature and high humidity, five test samples, #1 through #5, exhibited 10% or greater light white rust. The best of those, test sample #5, did not progress beyond about 10% light white rust through the 12-week test cycle. The other lubricants exhibited 20 to 40% white rust after the 12-week test. Test sample #6 provided the most corrosion resistance. This material resulted in virtually no corrosion after the 12-week cycle. Control panels, with no lubricant applied, exhibited 20% light white rust after 12 weeks in the high humidity conditions. The control panel with no lubricant applied, stored at room temperature showed no corrosion after the 12-week cycle. In general, samples #1 through #5 performed no better than the control panels.

2.2.3.3 Observations on Non-Chemically Treated Hot Dipped Galvanized Steel

After 1 week exposure to the high temperature and high humidity, panels coated with test samples #1 through #5 all exhibited 25% or greater light white rust. At the end of 2 weeks exposure, all five systems exhibited at least 90% medium white corrosion. The control samples, with no lubricant, also exhibited 90% medium white corrosion after the 2-week exposure. There were no quantifiable differences among these five compounds. Test sample #6 showed less than 5% light white rust through 9 weeks of exposure. Corrosion peaked at 30% medium to heavy white rust after 12 weeks of exposure. The room temperature stack for test sample #6 showed no corrosion after 12 weeks. Samples with test sample #1 showed 50% white corrosion. Samples with test samples #2 through #5 exhibited at least 80% corrosion when stored at room temperature.

2.2.3.4 Observations on Chemically Treated Galvalume® Coated Steel

All lubricants performed similarly through 9 weeks of high humidity high temperature testing. After 12 weeks of exposure white rust was noted as follows: test sample #1 - 70%, test sample #2 - 50%, test sample #3 - 20%, test sample #4 - 30%, and test sample #5<10%, control panels with no lubricant applied 50% corrosion. The test sample #6 panel showed no corrosion after 12 weeks exposure. None of the room temperature stack controls showed any corrosion after 12 weeks. The final 12-week performance in this test was similar to that of the chem-treated hot dip galvanized specimens.

2.2.3.5 Conclusions of Stack Testing

As an initial screening tool the stack tests identify only test sample #6, SLS-54, as providing significantly greater corrosion protection properties than the other compounds. In tests with non-chem-treated galvanized steel, test sample #6 did not exhibit significant corrosion until between six and nine weeks exposure. Other systems exhibited significant corrosion after one week. This suggests that if the non-chem-treated galvanized steel coils are to remain viable products, corrosion inhibiting lubricants (Group C Category) will be required.

The chem-treated panels exhibited significantly less corrosion than the non-chem-treated panels, no matter which lubricant was applied. The chem-treated panels were rated as withstanding about ten times more exposure before equivalent corrosion. All chem-treated hot dip galvanized specimens had the same chemical treatment and were from a single supplier. This does not imply that all chemical treatments will perform exactly the same but the results are a valid barometer for comparison.

2.2.4 Forced Air Tests

2.2.4.1 Forced Air Test Description

The purpose of these tests was to determine what effect, if any, the addition of fans placed above and below the roll forming line would have on the evaporation rates of various lubricating compounds tested. The tests were conducted at the Wheeling Corrugating Company manufacturing facility in Kansas.

The lubricating compounds evaluated in this test were:

<u>Group A</u>:
Lubricants that are 100% volatile organic solvents.
SLS-12, SLS-43, SLS-45

<u>Group B</u>:
Lubricants that are 95% volatile organic solvents, and 5% of added compounds.
SLS-50, WL-1

<u>Group C</u>:
Lubricants that contain some evaporable solvent, with the addition of significant quantities of residual material.
SLS-54

<u>Group D</u>:
Lubricants in this group consist of water-soluble compounds. These compounds are not emulsifiable, and do not contain any 'oils'.

<u>Group E</u>:
This group consists of lubricants that are emulsions of oil in water, but none of these were evaluated.

2.2.4.2 Forced Air Test Observations

The observations that were made are summarized in Table 2.2.3.

2.2.4.3 Conclusions of Forced Air Tests

The application technique used by Wheeling Corrugating provided a light application of lubricant. Type A lubricants evaporated well even without the use of fans. Type B lubricants, which take a little longer to evaporate based on the Sunderman tests, did benefit some from the use of two fans. Type C and D lubricants did not effectively evaporate with or without the use of fans. It should be noted that the Type D lubricant is a water-based product and does not contain the evaporable volatile solvent.

This study is only intended to give an indication of the feasibility of using fans for accelerating the evaporation of various lubricants. While some improvements were noted based on visual observations, the effectiveness or feasibility of using fans would depend on several factors, including application technique, line speed, ambient conditions, and air flow distribution.

Several lubricants were checked after they had been in a stacked pile for several minutes (15+). There was no apparent difference in the amount of residual lubrication left on the sheets when they were pulled apart and viewed.

Table 2.2.3 Forced Air Test Observations

		Panel Condition at End of Line	
Sample ID	**Group Type**	**Without Fans**	**With Fans**
Dry Run	N/A	Panel surface completely dry to the touch.	Panel surface completely dry to the touch.
WL-1	B	Very little residue left on sheets after roll formed and stacked.	With one fan operating, no apparent difference noticed. With both fans operating, sheet had very little residue and felt dry to the touch.
SLS-50	B	Very little residue left on the sheet after roll formed and stacked.	With one fan operating, no apparent difference noticed. This lubricant appeared to have the same results as WL-1.
SLS-43	A	Slight residues could be seen, but sheet felt slightly dry.	When run with both fans, this lubrication looked and felt the same as with no fans.
SLS-45	A	Slight residue left behind.	When run with both fans, the profile was slightly drier, but still left some residue.
SLS-29	D	Left behind “wet droplets” on the sheet.	With both fans running, the same “wet droplets” were left on the sheet. No difference.
SLS-54	C	A medium oily residue was left on the sheet.	With both fans running, the same medium oily residue was left on the sheet.
WL-2	B	Light residue.	With both fans running, same light residue was left on the sheet.

2.2.5 Forming Tests

2.2.5.1 Forming Test Description

The lubricants were evaluated by roll forming 50 one-foot pieces of G90 0.019 in. CTHDG and 50 one-foot pieces of AZ55 0.019 in. CT Galvalume® sheet. The rolls were inspected for metal pick-off and the roll formed pieces were inspected for black roll form marks. The lubricant was wiped onto a panel and it was run through the roll former within a count of two. The profile rolled by this mill does not represent any specific commercial product. The profile is a series of 'V' grooves with various radii. Seven variations were used: the six test lubricants and no lubricant. Results are shown in Table 2.2.4.

Table 2.2.4. Results of Formability Tests

Lubricant tested	AZ 55 Galvalume® sheet		G 90 HDG	
	Marks on Panels	Metal on Rolls	Marks on Panels	Metal on Rolls
No Lubricant	Slight	Slight	None	Slight Galling
SLS-12	None	None	None	None
SLS-29	None	None	None	None
SLS-43	None	None	None	None
SLS-45	None	None	None	None
SLS-50	None	None	None	None
SLS-54	None	None	None	None

2.2.5.2 Conclusions of Formability Tests

These roll forming tests showed that all of the lubricants that were evaluated prevented metal marking and metal pick-off on galvanized sheets and on Galvalume® sheets. This evaluation was conducted on 50 lineal feet of metal. Factory production involves the roll forming of thousands of lineal feet of product. Therefore, a lack of pick-off or marking in this test does not necessarily imply that these lubricants would provide the same results after extended production runs. It only indicates that each of these lubricants has the potential for eliminating marking and pick-off. However, each of the tested lubricants does represent a product that is being used in some production run. This use is either singular or in combination with mill applied lubricants.

3.0 SYNOPSIS OF EVALUATIONS

1) Lubrication is a necessary part of the roll forming operation. Without some type of lubrication at the roll former/metal interface galling of the metal surface will occur. This lubrication can be provided in many different ways. It can be provided with an evaporative compound that evaporates from the surface after the lubricating has taken place. The lubricant can be an oil type material, which does not evaporate for long periods of time. Certain paints are formulated to resist the effects of the roll-forming process.

2) Galvanized steel and Galvalume® sheet need some type of protection to prevent storage staining. This protection can be provided by using a chemical passivation treatment. The surface can also be protected with a rust inhibitive lubricant. These compounds usually have the appearance of light oils. A drawback to the light oils is that a residual film is left on the surface.

3) The terminology used to describe the class of compounds investigated in this study causes considerable confusion in the industry. Terms are used that do not have precise meanings and the same terms are used for different materials. For Example:

    a. One of the compounds evaluated is called both a 'Lubricating oil' and an 'Evaporating oil' by its manufacturer. It is in fact a 100% volatile organic solvent that does not contain any oil.

    b. Another manufacturer calls his material a 'Vanishing oil'. This material is in fact an aliphatic hydrocarbon solvent with approximately 3% non-volatile material. It is not 100% volatile.

    c. Still another manufacture describes his material as a 'Vanishing oil'. This material is in fact a corrosion inhibiting protective oil with only approximately 50 % weight volatile.

    d. Without universally accepted definitions of terms for these lubricants, confusion will continue.

4) In the evaporation rate study, five different groups of lubricants were identified. These groups were established based on the evaporation rates of the lubricants. These groups are identified as:

    a. <u>Group A</u> – Lubricants that are 100% volatile organic solvents.

    b. <u>Group B</u> – Organic solvent based lubricants that are greater than 95% volatile.

    c. <u>Group C</u> – Lubricants that do not completely evaporate under normal atmospheric conditions.

    d. <u>Group D</u> – Water-soluble non-emulsifiable lubricants that do not contain any oil.

    e. <u>Group E</u> – Lubricants that are emulsions of oil and water.

5) Lubricants in Group A do not leave any measurable residue on the surface of the lubricated sheet. Lubricants from Group B and Group D leave some small amount of material on the surface of the sheet. However, to the casual observer, the surface would be considered to be dry. Lubricants from Group E leave a small amount of residual oil on the surface of the sheet. Lubricants from Group C have the most residual material left on the sheet. If these lubricants are applied at levels higher than the manufacturer recommended levels they could be detectable on panels in the field as an oily film.

6) Preliminary evaluations indicate that all of the lubricants under consideration provide some resistance to galling and metal marking of the galvanized sheets and Galvalume® sheets. The evaluations conducted in this study are of short duration only. Extended run times must be conducted to establish the suitability of each lubricant.

7) In the industry, Lubricants in Group C are sometimes referred to as vanishing oils and slushing oils. These oils contain corrosion inhibiting materials. They are intended to prevent the formation of storage staining on galvanized sheets and Galvalume® sheets as well as provide lubrication for roll forming.

8) Lubricants from Group A, B, D and E are all applied to the metal sheet immediately prior to the roll forming operation. Lubricants from Group C are applied at the mill and are also used immediately prior to the roll forming operation.

9) It is possible to roll-form some metal deck and metal roofing profiles with lubricants that leave little or no residue on the metal surface. Some lubricants that leave a residue on the sheet are intended for corrosion inhibition considerations. The present studies conducted by the Lubricant Task Group do not address the question of what level of corrosion resistance is needed for certain end products. This is a question that can only be answered by the individual manufacturing company.

10) These studies, conducted by the Lubricant Task Group, have not addressed the questions of safety of the various lubricants within a manufacturing environment. They have also not addressed questions relating to environmental effects of these materials.

11) *Acrylic-coated sheet* is Galvalume®, or galvanized sheet that has been protected with a proprietary corrosion inhibitive acrylic coating. The primary purpose of this coating is to prevent storage staining and prevent pick-off and galling of the Galvalume® sheet. The major manufacturers of Galvalume® sheet have produced many thousands of tons of this product to the industry. Presently, the acrylic coated Galvalume® sheet is limited to use as building panels and roofing panels. Acrylic-coated galvanized sheet has seen limited use for decking products. The requirements of metal decking are different than those for metal roofing.

12) Limited in-plant testing was performed to determine the feasibility of roll forming Galvalume® metal roofing from dry, chemically treated coils. Test runs on a roof profile produced unacceptable pick-off of the metallic coating, even with the generous application of a Group A lubricant. Therefore, this was not included as a possible alternative to roll forming Galvalume® metal roofing panels.

4.0 GENERAL RECOMMENDATIONS

Based on the results of the evaluation conducted by the Lubricant Task Group, we offer the following recommendations.

1) Metal deck and metal building panel manufacturers have wide variations in the types of equipment used to manufacture their various products. Therefore, each manufacturer will have to establish his own set of parameters that best address the roll forming problems. This is particularly important in the determination of safety and environmental impact of highly evaporative lubricants in complying with local and state regulations.

2) Where possible, highly evaporative forming lubricants, which leave little residual material on the formed sheet, should be used to prevent galling.

3) The term 'Vanishing oil' should not be used to refer to these groups of lubricants. Suggested nomenclature is 'Evaporative Compound or Evaporative Lubricant' to identify materials that evaporate from the surface under normal atmospheric conditions. Compounds applied primarily to prevent storage stain and provide lubrication for roll-forming that do not completely evaporate under normal conditions should be referred to as 'Corrosion Inhibiting Lubricants'. The lubricant manufacturers should establish a revised nomenclature.

5.0 SPECIFIC RECOMMENDATIONS FOR ROLL FORMING LUBRICANTS

Metal deck and metal roof panels are normally manufactured under slightly different sets of conditions. Therefore, it is appropriate to provide solution objectives for each industry separately. The following recommendations are presented to reduce the potential for contaminants on formed metal walking surfaces.

5.1 Metal Roofing Panels

The objective for as-delivered roofing products is to eliminate or minimize the presence of visible liquid lubricants and dry residues that might increase the slipping hazard.

The following recommendations are made for manufacturers of metal roofing to comply with the stated objective. Note that "highly evaporative" lubricants are defined as a lubricant with greater than 95% volatiles by weight. This information can be deduced from the MSDS sheets. Note that the use of highly evaporative lubricants may also involve safety and/or environmental considerations as noted in the General Recommendations.

5.1.1 Bare (Unpainted) Galvanized Sheet

1. Use acrylic-coated Galvanized sheet. These products come free of lubricants from the mill and the addition of roll forming lubricant is not

necessary under normal circumstances. If lubricant is required, only highly evaporative products are recommended. They should be used sparingly and applied discretely to minimize their presence in the flats of the panels.

2. Order dry, chemically treated coils from the mill. Follow the mill's recommendation for coil storage to minimize corrosion/staining of product before it is roll formed. Use highly evaporative products for roll forming lubricant. If highly evaporative lubricants are not effective in preventing galling/pick-off, Group C lubricants may be discretely applied in hard to form areas but are not recommended on flats that will be used as walking surfaces. **[Note that plant testing of this alternative was only performed on Galvalume®. Even though it was not found to be acceptable for Galvalume®, further evaluation is suggested for galvanized metal roofing to determine the feasibility of this method. The survey discussed in Section 2.2.2 indicated that this option is possible for some products.]**

3. Order lightly oiled (Group C) coils from the mill. If additional roll forming lubricant is required, use highly evaporative products. These additional roll-forming lubricants should be used sparingly and applied discretely to minimize their presence in the flats of the panels. Since residues might be present on the walking surfaces of roofing products roll formed from lightly oiled coils, they should only be used on low slope applications and appropriate warning labels are also recommended. **[Note that this alternative may be removed if plant tests for the second alternative are successful.]**

5.1.2 Bare (Unpainted) Galvalume® Sheet

1. Use acrylic-coated Galvalume® sheet. These products come free of lubricants from the mill and the addition of roll forming lubricant is not necessary under normal circumstances. If lubricant is required, only highly evaporative products are recommended. They should be used sparingly and applied discretely to minimize their presence in the flats of the panels.

2. Order lightly oiled (Group C) coils from the mill. If additional roll forming lubricant is required, use highly evaporative products. These additional roll-forming lubricants should be used sparingly and applied discretely to minimize their presence in the flats of the panels. Since residues might be present on the walking surfaces of roofing products roll formed from lightly oiled coils, they should only be used on low slope applications and appropriate warning labels are also recommended. If highly evaporative lubricants are not effective on the line in preventing galling/pick-off, Group C lubricants may be discretely applied in hard to form areas but are not recommended on flats that will be used as walking surfaces.

5.1.3 Painted Roofing

These products come free of lubricants from the coil coater or coil supplier and the addition of roll forming lubricant is not necessary under normal circumstances. If lubricant is required, only highly evaporative products are recommended and then only with the approval of the paint coating manufacturer and the coating applier. They should be used sparingly and applied discretely to minimize their presence in the flats of the panels.

5.2 Deck Products

The objective for “As Shipped” Decking Products is to eliminate the presence of visible liquid lubricants and minimize dry residues that might increase the slipping hazard.

5.2.1 Guidelines for Coil Ordering and Product Marketing

1) Recognize that lubricants on coils & rolled product have two sources, the mill and the plant.

2) Establish steel ordering practices to eliminate mill lubricants when other service conditions allow this option.

3) Use prime painted coils on walking and work surfaces (whether galvanized sheet or cold rolled substrate) when other service conditions allow this option.

4) Use oil free cold rolled product for walking and work surfaces when other service conditions allow this option.

5.2.2 Recommendations for “In Plant” Practices

1) When necessary for roll forming galvanized steel, use rolling lubricants that are highly evaporative. For this purpose, “highly evaporative” is defined as a lubricant that is greater than 95% evaporative by weight. Note that the use of highly evaporative lubricants may also involve safety and/or environmental considerations as noted in the General Recommendations.

2) Control rolling practices & methods of rolling lubricant application.

3) Avoid applying rolling lubricants on painted products. These paints are typically formulated to facilitate roll forming.

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