Alternative Low-VOC Release Agents and Mold Cleaners for Industrial Molding, Concrete Stamping and Asphalt Applications

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DISCLAIMER

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EXECUTIVE SUMMARY

Release agents are used in a variety of different applications to prevent certain materials from sticking to a substrate. In concrete stamping, contractors use stamp mats to stamp a pattern into the concrete to mimic the look of stone. Mineral spirits are used on the bottom of the stamp mats and on the curing concrete to prevent the concrete from sticking to the mat so it can be moved to other parts of the concrete area for stamping. Asphalt is produced in manufacturing plants and used by cities and private contractors on roads, highways and other surfaces as temporary or permanent patches. Diesel fuel is used on drums and conveyors in the manufacturing plants and on the truck liftgates, tractors, shovels and rakes used to apply the asphalt to prevent it from building up and sticking. Parts made from a range of different substrates, including fiberglass, composite, foam, concrete and plastics, are molded into the desired form in manufacturing plants. Release agents, consisting of mineral spirits and resin are used on the molds to present a slick surface so the molded parts do not stick and can be removed easily from the mold surface. Styrene is used as a cleaning agent for certain fiberglass molds when the manufacturers rely on wax based mold release agents which build up over time. Hexane is used to remove mold protectant from metal molds before they are used in molding operations.

Mineral spirits, diesel fuel, styrene and hexane are all VOCs and they either are toxic or may contain toxic components. Styrene is considered to be a carcinogen and hexane causes peripheral neuropathy. Emissions of these materials from release applications are high and finding low-VOC, low toxicity alternatives that perform well and are cost effective is a challenging task.

This document summarizes the results of a project, sponsored by EPA Region IX and the South Coast Air Quality Management District (SCAQMD), to find alternatives to the VOC materials used today in release applications. SCAQMD is located in Southern California and regulates VOC emissions from activities in the area including Los Angeles, Orange, Riverside and San Bernardino Counties. The South Coast Basin is designated as nonattainment for ozone and VOC emissions need to be reduced further in the area. The Institute for Research and Technical Assistance (IRTA), a nonprofit organization established in 1989, conducted the project. IRTA's aim is to identify, develop, test and demonstrate safer alternatives in a range of different consumer product and industrial applications. Much of IRTA's work has addressed solvent alternatives. In this project, IRTA focused on finding low-VOC alternatives for the mold cleaners and the release agents used in concrete stamping, asphalt operations and parts manufacturing. The work involved evaluating the performance and cost effectiveness of the alternatives. IRTA also estimated the VOC emissions from the sectors of interest.

Concrete and Concrete Overlay Stamping

IRTA worked with two companies who supply products, including release agents, for the concrete and concrete overlay stamping industry. In concrete stamping, color packets are often added during the stamping process to achieve the desired effect. In concrete overlay stamping, where a thin layer of concrete is poured, color packets may be added during the stamping process but, most often, the color is added to the overlay later. IRTA conducted testing of low-VOC alternatives that could be used to replace the mineral spirits used today in these applications.

The best alternative for both colored and uncolored concrete is a petroleum based lubricant made by Dodge Oil. This material has low volatility and low VOC content and does not compromise the appearance of colored concrete. This product is more costly to use in the stamping process then mineral spirits. Because of its lower volatility, however, less of it may be required in field applications and this could reduce the cost

of using this alternative. For uncolored concrete, three alternatives worked effectively. Only one of these, however, is low enough in cost to be considered viable. This alternative is a recycled vegetable oil made by Promethean Biofuels with low VOC content and it is less costly than mineral spirits. Powder release agents have been used historically and they are also a low cost alternative to the liquid release agents using mineral spirits. Another option that has future potential is to use a non-stick coating on the stamp mats so no release agent would have to be used. IRTA did test some of these coatings but more testing would have to be performed to find a viable product. Table E-1 summarizes the best alternatives for the concrete stamping sector.

Table E-1
Alternative Low-VOC Release Agents for Concrete Stamping

Operation	Alternative Release Agent	Characteristics
Concrete Stamping	Dodge Oil Product	Colored and Uncolored Concrete
	Recycled Vegetable Oil	Colored Concrete
	Powder	Colored and Uncolored Concrete

Asphalt Manufacture and Application

IRTA worked with an asphalt manufacturer and a city and private contractor, who apply asphalt to roads and other surfaces, to test alternative low-VOC materials. IRTA tested four different products and the recycled vegetable oil, which was also tested for concrete stamping, performed best. Although the vegetable oil is somewhat more expensive than the diesel fuel used today, it is lower in volatility than diesel fuel so less of it could be used when it is applied in the field application. This could reduce the overall cost of using it. Two other alternatives, Bango 250 and Holly 70, which are petroleum based lubricants with low VOC content, were also tested for asphalt application. Although they did not perform as well as the recycled vegetable oil, they are viable alternatives. Both are more costly than diesel fuel but, since they are lower in volatility, less of them could be required in the field. Table E-2 summarizes the alternatives that can be used in the asphalt sector.

Table E-2
Alternative Low-VOC Release Agents for Asphalt Manufacture and Application

Operation	Alternative Release Agent	Characteristics
Asphalt Manufacture	Recycled Vegetable Oil	
Asphalt Application	Recycled Vegetable Oil	
	Bango 250 and Holly 70	Higher Cost Alternatives

Molded Parts Manufacture and Mold Cleaning

IRTA worked with seven different companies who manufacture parts using molding operations. These companies use high VOC content mold release agents and/or mold cleaners in the molding process. The companies make fiberglass boats, fiberglass recreational vehicle parts, composite aerospace parts, foam parts, concrete pilings and vaults and plastic food service parts. The best alternative mold release agent for nearly all cases is a water-based material; in one instance a release agent specially formulated for this project that using PCBTF was the best alternative. For concrete parts molding, the best alternatives are the Dodge Oil product and recycled vegetable oil which were also tested for concrete stamping. The best alternative option for cleaning fiberglass molds is to adopt alternative liquid release agents that don't

require cleaning. The best option for cleaning metal molds is to use a dry ice blasting system to remove the mold protectant. Table E-3 summarizes the alternative options for this sector.

Table E-3
Alternative Low-VOC Release Agents for Molded Parts Manufacture and Cleaning

Operation	Alternative Release Agent	Characteristics
Fiberglass Parts Manufacture	Water-Based Release Agent	
Composite Parts Manufacture	Water-Based Release Agent	
Foam Parts Manufacture	PCBTF Release Agent	
Concrete Parts Manufacture	Dodge Oil Product	
	Recycled Vegetable Oil	
Fiberglass Mold Cleaning	Water-Based Release Agent	No Cleaning Needed
Metal Mold Cleaning	Dry Ice Blasting	Low Cost Option

Inventory of VOC Emissions

As part of the project, IRTA also estimated the VOC emissions from release agents in the sectors of focus. IRTA worked with a number of suppliers to make these estimates and they are presented in Table E-4. The values demonstrate that the emissions from the Asphalt industry are the highest, possibly up to seven tons per day, while acknowledging diesel's relatively low volatility. A range of emissions is provided for the concrete stamping sector; emissions may be more than one ton per day in this sector. Manufacturing plant emissions are estimated at slightly less than one ton per day.

Table E-4
Release Agent Inventory

Sector	Inventory (Tons Per Day)
Concrete and Concrete Overlay Stamping	0.32 to 1.17
Asphalt Manufacturing and Use	7.14
Parts Manufacturing	0.92
Form Release	0.08
Total	8.46 to 9.31

Summary of Findings

The results of the project demonstrate that there are low-VOC alternatives to the mineral spirits release agents used in concrete stamping and for manufacturing parts. There are also low-VOC alternatives to the diesel fuel currently used by the asphalt industry. If these alternatives were adopted, they have the potential to reduce VOC emissions in the South Coast Basin by as much as nine tons per day.

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I. INTRODUCTION AND BACKGROUND

There are thousands of manufacturers, contractors and public works departments in the United States that rely on release agents to manufacture parts in molds, provide concrete and concrete overlay stamping services and produce asphalt and use it in maintaining and building roads. In all of these applications, release agents are generally used to ensure that the parts, the concrete or the asphalt does not stick and will release readily from the substrate. The release agents used in these applications today are generally high VOC materials and emissions from their use are significant. Some companies that mold parts in industrial applications also clean their molds and, in general, use high VOC materials for that purpose.

VOC emissions from release agents and cleaners contribute substantially to the South Coast Air Basin's inventory. The South Coast Air Quality Management District (SCAQMD or District) is responsible for controlling air emissions in four counties in Southern California including Los Angeles, Orange, San Bernardino and Riverside. The SCAQMD periodically adopts Air Quality Management Plans and the most recent plan calls for reductions in VOC emissions from release agents to help in achieving attainment status.

The District controls VOC emissions from release operations to some extent in Rule 442 "Usage of Solvents" but there is not currently a specific regulation that applies to the operations. Rule 442 specifies that companies shall not emit more than 833 pounds of VOCs per month from all VOC containing processes subject to the rule. This is a very high limit and most companies using VOC emitting mold release agents and cleaners have VOC emissions below the limit. The District controls emissions from concrete forming in Rule 1113 "Architectural Coatings." The release materials used in concrete and concrete overlay stamping are not currently regulated in the rule. The District has two regulations, Rule 1108 "Cutback Asphalt" and Rule 1108.1 "Emulsified Asphalt," that regulate the composition of the asphalt itself but do not regulate release agent emissions from asphalt operations.

The Institute for Research and Technical Assistance (IRTA), a nonprofit organization, was established in 1989 to identify, develop test and demonstrate safer alternatives in industrial and consumer product applications. IRTA's work has a heavy focus on solvent alternatives. IRTA staff have worked with hundreds of facilities in the South Coast Basin to identify, develop, test and demonstrate low-VOC, low toxicity alternatives.

The SCAQMD received a grant from EPA Region IX to identify and demonstrate low-VOC alternatives for mold release and cleaning applications. SCAQMD contracted with IRTA to conduct the project. As the project evolved, additional applications, including release agents used in concrete stamping and asphalt operations were added to the project. The results of the testing are presented here.

1.1 Participating Facilities

Many contractors use polyurethane mats with a pattern to stamp the concrete while it is curing. These stamp mats are used in both concrete and concrete overlay stamping operations. The liquid release agents used currently are high VOC content mineral spirits. Asphalt is manufactured in plants and is sold to private contractors and government public works departments which are responsible for building and maintaining roads. Diesel fuel is generally used as a release agent for production plant equipment and on the equipment used to apply the asphalt. Parts made of a variety of substrates are manufactured by molding them into the desired shape. Parts are made of fiberglass, a range of different polymers and concrete and they are used to manufacture boats, aircraft and other vehicles like RVs, in pilings used for constructing piers and in the aerospace and food industries. In these applications, the mold release agents are generally based on mineral spirits and the mold cleaners are generally VOC solvents of various kinds.

During the project, IRTA worked with a variety of different companies to formulate, test and demonstrate low-VOC alternative release agents and cleaners. A list of the companies IRTA worked with to conduct the testing is provided in Table 1-1.

Table 1-1
Facilities/Organizations Participating in the Release Agent Project

Company	Type of Operation	Alternatives Investigation
Proline	Concrete Stamping	Release Agents
Multicoat	Concrete Overlay Stamping	Release Agents
Escondido Asphalt	Asphalt Manufacturer	Release Agents
City of Simi Valley	Asphalt Operations	Release Agents
Asphalt and Grading Paving Company	Asphalt Operations	Release Agents
Anonymous Boat Manufacturer	Fiberglass Boats	Mold Cleaners and Mold Release Agents
FinCo	Fiberglass Parts	Mold Release Agents
KF Fiberglass	Fiberglass RV Parts	Mold Cleaners
Foam Molders	Foam Parts	Mold Release Agents
M.C. Gill	Composite Aerospace Parts	Mold Release Agents
Oldcastle Precast	Concrete Parts	Mold Release Agents
Cambro	Food Service Parts	Mold Cleaners

The facilities, suppliers or organizations that participated in the project have or represent a variety of different operations that use VOC emitting release agents or cleaners. Proline is a supplier of concrete stamping release agent and stamping mats to contractors. The release agent supplied by the company relies on mineral spirits. Multicoat is a supplier of materials used in concrete overlay stamping operations, including mats and release agent. The release agent supplied by the company is based on mineral spirits.

Escondido Asphalt is an asphalt manufacturer; the company uses diesel fuel as a release agent for a range of plant operating equipment. The City of Simi Valley and Asphalt and Grading Paving Company currently use diesel fuel as a release agent for their asphalt application equipment.

Anonymous Boat Manufacturer uses molds to make fiberglass boat hulls and boat parts. FinCo is a job shop that uses molds to make a range of different fiberglass parts. KF Fiberglass manufactures fiberglass parts for recreational vehicle shower stall systems and other RV parts. Foam Molders uses molds to make foam parts used in packaging and other applications. M.C. Gill manufactures composite aerospace parts for aircraft. Oldcastle Precast uses molds to make large cement parts that are used in a variety of applications including supports for piers and utility vaults. Finally, Cambro uses compression molding to manufacture parts used in the food service industry from a range of different polymers.

In addition to Proline and Multicoat who helped with testing, IRTA also worked with several suppliers over the course of the project. Six suppliers, in particular, assisted IRTA in accomplishing one or several of the tasks. The first was Solomon Colors, an out of state supplier who provided input for the inventory estimates and discussions of alternatives for concrete stamping. The second was Dodge Oil who provided several

different formulations for concrete and asphalt release agent testing and accommodated IRTA in reformulation when necessary. The third was WD 40 Company who provided a low-VOC release agent for tests in concrete and asphalt release agent testing. The fourth was Promethean Biofuels who provided recycled vegetable oil formulations for concrete and release agent testing. The fifth was Specialty Products Co. (SPC) who provided water-based mold release agents and worked with IRTA to formulate release agents with exempt chemicals. SPC also helped with some of the testing. The sixth was Specialty Materials who provided an exempt chemical for concrete stamping release agent tests, formulating mold release agents and formulating mold cleaners.

IRTA worked with the facilities and organizations listed in Table 1.1 and the other suppliers to estimate the inventory of VOC emissions in the applications of interest and to find alternatives for the operations. In some cases, IRTA worked with the facilities to test alternative release agents. In other cases, IRTA worked with the facilities to test alternative mold cleaners. IRTA also worked with some facilities to test alternative technologies.

1.2 Project Approach

In general, the first step in the project was to visit the participating facilities or organizations to discuss the operations that would be the focus of the work. The second step was to identify low-VOC alternatives that might be suitable for the operations. In some cases, this involved formulating new materials for testing. In all cases, IRTA focused on developing or finding alternatives that had a VOC content of 25 grams per liter or less. The third and fourth steps were to conduct initial and scaled-up or field testing of the alternatives. In some instances, during these steps, IRTA provided larger quantities of the alternative for testing. The fifth step was to analyze and compare the performance and cost of the alternatives to the currently used materials. The sixth step was to write the final report.

1.3 Alternatives Performance

Performance of the low-VOC alternatives at each facility or organization was evaluated on a case-by-case basis. In all cases, the plant personnel or the suppliers provided information on their requirements for the process. It was important that the alternative perform as well as or better than the material used currently.

1.4 Cost Analysis

IRTA performed cost analysis for each of the alternatives that was successfully tested at the participating facilities and organizations. Depending on the operation, the types of costs that were evaluated included:

- Capital cost
- Release agent cost
- Cleaner cost
- Labor cost
- Utilities cost
- Other related operation costs

These costs were evaluated and compared where appropriate when they were different for the current operation or for the operation where the alternative would be used.

In the one case where a capital equipment cost was required, the cost of capital was spread over a 10 year period. The interest rate for the cost of capital was assumed to be four percent which would overestimate

the cost of using the alternative. In all cases that involved an alternative release agent and/or cleaner, the costs were different and they were compared. In one case, there was a difference in the electricity cost and this was noted. In a few cases, there would be differences in other costs related to the operations and these were also noted. In one case where an alternative technology was evaluated, the data were not provided to IRTA so the cost could not be estimated.

1.5 Report Organization

Section II of this report provides detailed information on the testing and analysis that was conducted with the facilities or organizations involved in concrete stamping and asphalt operations. The cost of the current and alternative materials or processes was evaluated and compared. Section III of the report provides similar information for the facilities using mold release agents and mold cleaning in manufacturing processes. Again, the cost of current and alternative materials and processes is analyzed and compared. Section IV presents estimates of the inventory of the VOC emissions from the concrete stamping, asphalt and parts molding sectors. It also identifies two problems that could arise with the use of some of the alternatives that were tested. Section V of the report summarizes the project findings. Appendix A includes Material Safety Data Sheets (MSDSs) for the currently used materials and the alternatives in the concrete stamping and asphalt sectors and Appendix B provides MSDSs for the materials and alternatives used in the mold release agents and cleaners in the parts manufacturing sector. Finally, Appendix C presents information on toxicity tests currently underway for one of the alternatives.

II. Concrete and Concrete Overlay Stamping and Asphalt Sectors

2.1 Concrete and Concrete Overlay Stamping Operations

Stamped concrete is commonly referred to as imprinted concrete or textured stamped concrete. It is concrete that is designed to resemble a variety of natural materials like brick, flagstone, stone, wood, cobblestone and slate. Stamped concrete can be used to aesthetically enhance the interior or exterior of a residential or commercial structure and is used for floors, walls, driveways, patios, pool decks, entries and courtyards. A wide range of patterns and colors are available for stamped concrete.

When concrete has become damaged or unsightly, there are two options for improving it. The first option is to remove the concrete and pour new concrete. The second option is to use a concrete overlay material over the original concrete. The overlay is a thin surface restoration material that differs from concrete itself in that it contains a polymer resin which bonds to the concrete below. Both concrete and overlay concrete can be stamped with a pattern.

The pattern is stamped with rubber imprinting tools or stamps or stamp mats that are impressed into the concrete or concrete overlay. The stamp mats are manufactured from molds created from authentic stone or wood. When the concrete or concrete overlay is curing and reaches a plastic stage, a release agent is used to help release the stamp mats from the concrete without sticking. Release agents come in either a powder or liquid form. A picture of a typical stamp mat is shown in Figure 2-1.

Figure 2-1 Typical Stamp Mat

Powder release agents were used historically but, more recently, liquid release agents have become popular since they are considered less messy than the powder. Liquid release agents provide a lubricating barrier and decrease the friction between the stamp mat and the concrete surface. Some of the concrete is colored with powder colorants during the stamping process. The release agent can be used for stamping colored or uncolored concrete. Liquid release agent is generally applied using a pump type sprayer to the area of the concrete that will be stamped in the next few minutes, often about ten to fifteen square feet at a time. The

contractor places one concrete stamp mat next to another in the same pattern and can hop scotch the stamp mats over the entire surface of the concrete. The contractors stand on the mats and use hand tampers to pound the stamp mats into the concrete surface. The next day, the surface of the concrete is rinsed to remove any residual release agent. Pictures of the stamping process are shown in Figures 2-2, 2-3 and 2-4.

Figure 2-2 Spraying Stamp Mat with Release Agent

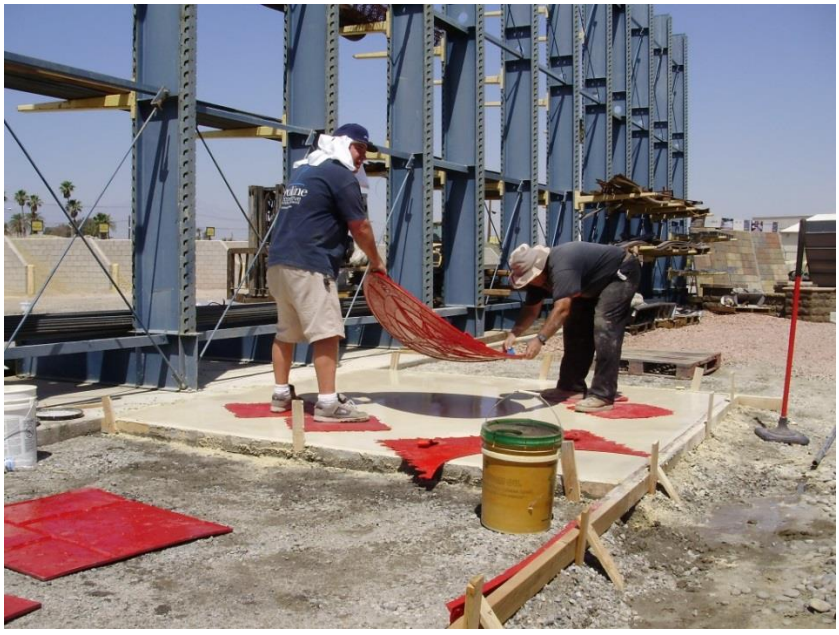

Figure 2-3 Laying Stamp Mat on Concrete

Figure 2-4 Standing On and Tamping Down Stamp Mats

The liquid release agent commonly used today is a mineral spirit. The agent also contains a small amount of a fatty acid which reacts with the alkaline concrete. It may contain a small amount of a surfactant which enhances the rinsing after the concrete has cured and may also contain a fragrance. The mineral spirits used in the release agent is a high VOC content materials. An MSDS for the material is shown in Appendix A.

The mineral spirits release agent used today functions very well because it forms a barrier between the concrete and the stamp mats. When concrete cures, water is driven from the surface of the concrete. The mineral spirits is not soluble in the water so the barrier it forms on the top of the curing concrete prevents the stamp mat from sticking to the concrete. The release agent is reapplied frequently and the mat ends up with only a small amount of concrete mix on the bottom; it can be moved from place to place to complete the stamping pattern throughout the entire concrete area.

IRTA conducted tests of alternatives to the high VOC content liquid release agents with two different types of facilities. The first facility, Proline, sells stamp mats and release agent for both concrete and concrete overlay stamping. The second facility, Multicoat, is involved in selling products for the concrete overlay market. The testing results with both facilities are described below.

2.1.1 Concrete Stamping Tests with Proline

Proline is a company located in Oceanside, California that manufactures and sells liquid release agents and stamp mats. IRTA conducted preliminary testing of a variety of different formulations with Proline to try to identify alternatives that could be used in place of the high VOC mineral spirits liquid release agent used today. Proline poured small areas of concrete mix so the alternatives could be tested. Alternatives that were tested initially included water-based and soy based cleaning materials with VOC contents of 25 grams per liter or less. These formulations did not work well because they tried to “clean” the concrete, resulting in discoloration. In addition, the water-based cleaners dissolved in the curing concrete since they are obviously water soluble.

IRTA then focused on testing water insoluble exempt chemicals and lubricant materials that had very low VOC content. The exempt chemicals that were tested were propylene carbonate and parachlorobenzotrifluoride (PCBTF). The propylene carbonate was not an adequate release agent because too much of the concrete mix stuck to it during the testing. The PCBTF worked effectively as a release agent but, when it was tested on colored concrete, it had a bleaching effect. Since most concrete is colored with powder color packets during the stamping process, this would not be acceptable. In contrast, in concrete overlay operations, the color is often added well after the stamping process so PCBTF would be a possible candidate as a release agent for part of the concrete overlay sector (see Multicoat below).

IRTA also tested three types of lubricant materials with low VOC with Proline. The first, a soy based lubricant, is made by WD 40. The second, a petroleum based lubricant, is made by Dodge Oil. The third, is a recycled vegetable oil made by Promethean Biofuel. Two of these materials, the WD 40 product and the recycled vegetable oil, had a bleaching effect on colored concrete. In the initial testing, after the original formulation was modified by the supplier, Proline indicated they thought the Dodge Oil product worked effectively and a field test was arranged to see how this material performed in scaled-up testing. Pictures of the preliminary tests are shown in Figure 2-5 and 2-6.

Figure 2-5 Preliminary Test of Release Agents for Stamping

Figure 2-6 Preliminary Stamping Tests with Dodge Oil Release Agent

In the field tests, Proline poured the traditional concrete mix and IRTA provided the Dodge Oil product in a spray bottle; this product contained the lubricant and a small amount of fatty acid. An MSDS for the material is shown in Appendix A. When the concrete was ready to be stamped, the product was sprayed on the concrete and the bottom of a small stamp mat. The mat was pounded into the concrete and the pattern was stamped. The bottom of the mat was inspected and the release agent had worked very well. The next day, after the concrete had cured, a hose was used to rinse the surface and the Dodge Oil product rinsed well. Pictures of the stamping tests are shown in Figures 2-7 and 2-8.

Figure 2-7 Poured Concrete for Dodge Oil Release Agent Field Test

Figure 2-8 Stamp Mat and Concrete After Stamping for Dodge Oil Release Agent

2.1.2 Concrete Stamping Alternatives Cost Analysis for Proline

IRTA conducted cost analysis to compare the cost of using the high VOC mineral spirits used currently and the Dodge Oil lubricant product which has a VOC content less than 25 grams per liter. Proline estimates their sales of mold release agents in 2011 in the South Coast Basin at 1,062 gallons. The company indicates that the market has increased by 15 to 20 percent since then. Assuming the market increase is 17.5%, Proline's sales are about 1,248 gallons per year. Proline indicates that the cost to their company for the mineral spirits they currently purchase is 98 cents per pound and they purchase it in totes which contain 275 gallons or 2,000 pounds. This translates into a cost of about $7.13 per gallon. They also add in a fatty acid at a cost Proline indicates is negligible. On this basis, Proline's costs for purchasing the release agent currently are $8,895 per year.

Proline sells their release agent to suppliers who, in turn, sell it to contractors at a retail price. Some of the material is sold to contractors who do concrete stamping and some is sold to contractors who do concrete overlay stamping. Proline indicated they would not be willing to sell release agents that may bleach concrete because they could not be sure what market they would be sold to. On this basis, Proline would probably sell only the petroleum-based alternative.

The Dodge Oil supplier indicates he would sell the petroleum-based product containing the small amount of fatty acid at a price of about $8.90 per gallon when it is purchased in tote or drum quantities. This product has a much lower volatility than the mineral spirits used today which indicates that less of it might be required since it would not evaporate as readily. IRTA performed the cost comparison by taking a conservative approach and assuming that the same amount of the alternative agent would be required. Table 2-1 shows the cost comparison for the mineral spirits used today and the petroleum-based product.

Table 2-1 Annual Cost to Proline for Purchasing Release Agents	
Release Agent	**Annual Cost**
Mineral Spirits	$8,895
Dodge Oil Product	$11,107

The values of Table 2-1 show that Proline's cost for purchasing release agent would increase by 25 percent if the same amount of the alternative release agent were required. If less of the alternative release agent were required because of the lower volatility, the cost to proline could be lower than the cost of mineral spirits.

2.1.3. Concrete and Concrete Overlay Stamping Tests with Multicoat

Multicoat sells a small amount of release agent and a few stamping mats to contractors so they can offer the full range of products. The main business of the company, however, is to provide products specifically to contractors who offer concrete and concrete overlay services. The company sells coatings and sealers used in concrete and concrete overlay operations. Multicoat agreed to test a variety of alternatives for stamping with IRTA.

The concrete overlay mix is stickier than the concrete mix so it was very important to verify how the products would perform in this application. As mentioned earlier, concrete overlay is sometimes colored during the stamping process and sometimes colored a day or so after the stamping process is completed. For this reason, some of the alternatives judged by Proline to bleach the colored concrete mix would not pose a problem if they were used for stamping in concrete overlay operations where color is not added during the stamping process. Multicoat and IRTA conducted initial tests of five different possible release agent alternatives at the Multicoat facilility. Multicoat prepared the concrete overlay mix in small pallets on cardboard. The five formulations that were tested included PCBTF, propylene carbonate, the WD 40 product, the Dodge Oil product that Proline preferred and a recycled vegetable oil made by Promethean Biofuels. Pictures of the test pallets and the testing are shown in Figures 2-9 and 2-10.

IRTA prepared each of the test formulations in spray bottles to mimic the pump spray equipment used in the field. They were applied to the curing concrete and the bottom of stamp mats. The stamp mats were placed on each of the pallets and they were tamped down. The bottoms of the mats were inspected. Four of the products, the PCBTF, the WD 40 product , the Dodge Oil product and the recycled vegetable oil performed well but the propylene carbonate sprayed mat retained a significant residue of the concrete indicating that it did not provide an adequate barrier. The next day, once the concrete had cured, the pallets were rinsed with water and all of them rinsed well. The concrete overlay was also colored the next day with a stain and the overlay stamped with each of the four agents accepted the stain well. MSDSs for the PCBTF, WD 40 and the recycled vegetable oil are shown in Appendix A.

Figure 2-9 Tests of Four Release Agents at Multicoat

Figure 2-10 Placing Stamp Mat for Release Agent Testing at Multicoat

2.1.4. Concrete and Concrete Overlay Stamping Alternatives Cost Analysis for Multicoat

IRTA performed a cost analysis and comparison for the four alternatives that performed well for concrete overlay mix. Again, Multicoat sells very little release agent but carries the product to offer a full range of products to contractors. Multicoat purchases their release agent in one gallon containers from a supplier like Proline. Multicoat purchases about 30 gallons per year at a cost of $16 per gallon. WD 40 indicates that a price for their product for one gallon purchases is $27.87 per gallon. Dodge Oil estimated a price of $12.90 per gallon if the customer purchased one to two five gallon pails at a time. A local supplier indicates he

would offer the PCBTF for $265 for a five gallon pail which translates into a price of $53 per gallon. The recycled vegetable oil supplier indicates that the retail price for his product is $9.94 per gallon.

Table 2-2 presents the cost comparison for the mineral spirits and the four alternative products for Multicoat. The PCBTF evaporates slightly more rapidly than the mineral spirits so a lower volume would not be used. The WD 40, Dodge Oil and recycled vegetable oil products have lower volatility than the mineral spirits so less of these alternatives might be necessary. To be conservative, IRTA assumed that use of all of the alternatives would be the same as use of the mineral spirits. The results indicate that the Dodge Oil product and the recycled vegetable oil are less costly to purchase than the mineral spirits. The WD 40 product and the PCBTF are much more costly to purchase.

Table 2-2
Annual Cost to Multicoat for Purchasing Release Agents

Release Agent	Annual Cost
Mineral Spirits	$480
PCBTF	$1,590
WD 40 Product	$836
Dodge Oil Product	$387
Recycled Vegetable Oil	$298

2.1.5 Industrywide Concrete and Concrete Overlay Stamping Release Agent Alternatives Cost Analysis

IRTA analyzed and compared the cost of using the mineral spirits release agent used today and the alternatives in concrete stamping operations. In Section IV of this report, IRTA developed estimates of the VOC emissions from concrete stamping in the South Coast Basin. The assumptions used to estimate the inventory are presented later but they are used here in the cost analysis. For purposes of analysis, IRTA assumed that 25,781 to 93,590 gallons of mineral spirits per year are used in the concrete stamping market and 8,594 to 31,196 gallons per year are used in the concrete overlay stamping market.

Nearly all of the concrete and concrete overlay that is stamped is also colored. Proline estimates that about 85% of the concrete stamping is colored during the stamping process. This means that the color packets are applied during the stamping process. Multicoat estimates that only about 30% of the concrete overlay stamping is colored during the stamping process. The Dodge Oil product can be used for all of the concrete and concrete overlay stamping operations. Since three of the alternatives tend to bleach the color, they can only be used for 15% of the concrete stamping operations and 70% of the concrete overlay operations. Based on the ranges given above, the colored concrete stamping market mineral spirits usage is 24,492 to 88,910 gallons per year. The similar figure for uncolored concrete stamping is 9,883 to 35,876 gallons per year.

Some contractors purchase their mineral spirits release agent from large supply stores and others purchase it directly from the supplier. One supplier indicates his company provides the release agent in five gallon buckets at a price of $13.20 per gallon. Supply stores have a higher price, about $21 per gallon. For the analysis, IRTA assumed that half the release agent would be purchased from the supplier at a markup of 85% from the tote price and half would be purchased in stores at retail prices which have a markup price of 195% over the tote price. The tote price for the mineral spirits is $7.13 per gallon. This results in an average price of $17.11 per gallon.

The same markups were assumed for the alternative release agents assuming a tote price of $8.90 per gallon for the Dodge Oil product and a tote price of $5.75 per gallon for the recycled vegetable oil. The tote price for the PCBTF is currently about $2 per pound or $22.20 per gallon. WD 40 does not have tote prices, so a drum price of $24.84 per gallon was used for the analysis. These assumptions result in average per gallon prices for the Dodge Oil product, the recycled vegetable oil, PCBTF and WD 40 of $21.36, $13.80, $53.28 and $59.62 respectively.

Three of the alternatives evaporate more slowly than the mineral spirits so less of these alternatives might be used in the stamping operation. To be conservative, IRTA compared the cost of using the alternatives and the mineral spirits assuming that usage would be the same. On this basis, Table 2-3 presents the cost comparison for the release agents in the colored and uncolored concrete market.

Table 2-3
Annual Cost Comparison for Industrywide Release Agents for Concrete Stamping

Release Agent	Colored Concrete Stamping		Uncolored Concrete Stamping	
	Low Estimate	High Estimate	Low Estimate	High Estimate
Mineral Spirits	$419,107	$1,521,428	$169,118	$613,910
Dodge Oil Product	$523,149	$1,899,118	$211,101	$766,311
WD 40 Product	NA	NA	$589,185	$2,138,784
PCBTF	NA	NA	$526,566	$1,911,473
Recycled Vegetable Oil	NA	NA	$136,385	$495,089

The values of Table 2-3 show that the cost of using the Dodge Oil product for colored and uncolored concrete stamping is about 25% higher than the cost of using the mineral spirits assuming the same amount of the product will be used. If less of the product were required because of the lower volatility, the cost of using the material could be lower than the cost of using the mineral spirits. For uncolored concrete, the figures of Table 2-3 show that the cost of using the recycled vegetable oil is 19% lower than the cost of using the mineral spirits. If less of the alternative release agent is required, the cost of using the recycled material could be substantially lower than the cost of using the mineral spirits. The cost of using the WD 40 product and the PCBTF are much higher than the cost of using the mineral spirits for uncolored concrete stamping. Less of the WD 40 could be required because of its lower volatility but it would likely still be a higher cost alternative than the mineral spirits. The volatility of the PCBTF is similar to the volatility of the mineral spirits so less of the alternative would not be required.

2.1.6 Powder Release Agents

The other option that can be used as an alternative to mineral spirits is powder. Powder has been widely used historically as a release agent for concrete stamping and concrete overlay stamping and the use of liquid release agent is fairly recent. One supplier estimates that, of the total stamping market, powder accounts for about 80% and liquid accounts for about 20%. As mentioned earlier, in the concrete overlay stamping process, the contractor seals and often colors the concrete overlay after stamping. The powder can interfere more with the sealer process in particular so liquid release is likely used more widely in the overlay stamping market than in the concrete stamping market.

A major reason powder is still used and used more widely than liquid release is that it is less costly. One supplier made a comparison. She indicated that the same coverage can be achieved with a 30 pound bucket

of powder which costs about $33.50 and a five gallon bucket of the liquid release which costs about $66. On this basis, the cost of using the powder in place of the liquid release agent would reduce the release agent cost by almost half. The cost of using powder in place of the mineral spirits release agent is lower than the cost of using any of the alternative liquid release agents.

2.1.7 Non-Stick Coating Alternatives

Another approach to finding an alternative to the high VOC release agents used in concrete and concrete overlay stamping today is to use non-stick mats for the stamping operation that would not require use of a release agent at all. IRTA conducted preliminary testing of non-stick materials to see if the option offered any promise. This testing involved using silicon based baking mats and pans to determine if these non-stick materials could serve as alternatives. IRTA worked with Multicoat and the company poured test concrete overlay mix and the results with the baking mats and pans indicated that the concrete did stick but was easily removed. This would not be adequate, however, because contractors could not stop and flush the mats between uses at a job.

To further pursue the concept, IRTA considered whether the mats could be made of a non-stick material. Many non-stick materials are too flexible, however, and contractors could not step on them and tamp them down as is the practice today. IRTA decided coating the bottom of the more substantial mats with a non-stick coating might be the next step. IRTA ordered samples of a silicon based coating and a fluoropolymer based coating and applied them to the bottom of stamp mats. The MSDSs for these coatings are shown in Appendix A. In this initial testing, the coatings seemed to work for the concrete mixture but not for the overlay mix which contains resin and is stickier. IRTA further tested the coated mats on the concrete mix and too much of the mix residue was left on the mats. Pictures of the testing of the mats with these coatings are shown in Figures 2-11, 2-12 and 2-13.

Figure 2-11 Testing Fluoropolymer Coating on Stamp Mat

Figure 2-12 Testing Silicone Coating on Stamp Mat

Figure 2-13 Residue of Concrete on Silicone Stamp Mat During Testing

Multicoat identified a new coating recently introduced to the market called NeverWet which is made by Rust-Oleum. It is an aerosol product that consists of a base coat and a topcoat; MSDSs for the two coatings are shown in Appendix A. In initial testing, Multicoat thought the coating performed well for the overlay mixture. IRTA and Multicoat conducted additional tests and the coating appeared to offer some promise. The testing indicated that the overlay mix did not stick to the mat at all. The coating was extremely good at preventing any residue. Pictures of the testing are shown in Figures 2-14 and 2-15. The problem with the coating, however, is its durability. It would not likely last on the mats in the alkaline conditions and aggressive tamping of the stamping process. The testing indicated that the coating might not last even for

one stamping job. Additional testing under field conditions would be necessary to determine whether the non-stick coating could be considered for this application.

Figure 2-14 Stamping Test with NeverWet Coating

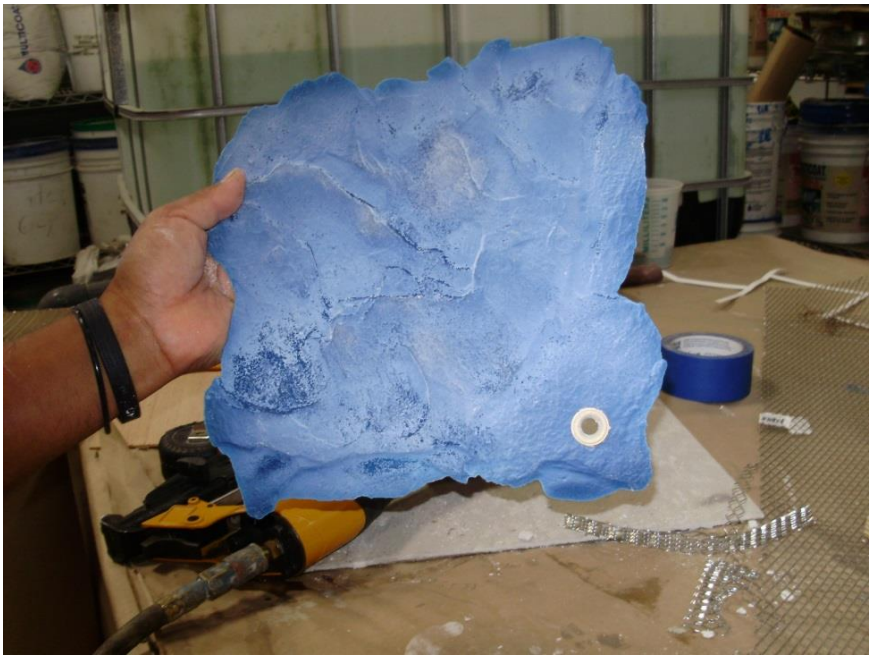

Figure 2-15 Stamp Mat After Stamping with NeverWet Coating

2.1.8 Cost Analysis for Non-Stick Coatings

IRTA performed a cost analysis for the NeverWet non-stick coating assuming it would only be used on one job and would need to be reapplied for each new job. To examine the cost effectiveness of this option, IRTA compared the cost of using the non-stick coating on the mats with the cost of using release agent for a typical stamping job.

An industry source estimates that the average contractor job for concrete or concrete overlay stamping would be about 1,000 square feet. A typical mat used for stamping is three feet by three feet or nine square feet. Contractors generally have six to eight mats so, for purposes of analysis, IRTA assumed the contractor would have seven mats. Based on the job of 1,000 square feet, this implies that each mat would be used 16 times.

A release supplier estimates that the mineral spirits release agent used today has a coverage of about 200 square feet per gallon. Assuming the 1,000 square foot job, about five gallons would be required. As described earlier, the tote price of the mineral spirits release agent is $7.13 per gallon. About half is sold in five gallon containers by the suppliers at a markup of 85% and half is sold in supply stores at a 195% markup. Assuming these prices, the contractor would pay a price of $17.11 per gallon on average. The total cost of the release agent for the 1,000 square foot job would amount to about $86.

The NeverWet coating consists of two products. The first product is a base coat which cures in about 30 minutes. The second product is a silicone topcoat which can be used after a period of 30 minutes but the instructions indicate that a longer curing time may be better. The product is sold in aerosol cans and a kit of the two cans is priced at $18.75 at Home Depot. The instructions indicate that this kit is suitable for coating between 10 and 15 square feet of surface. The seven mats used for the typical job have a 63 square foot surface area. Assuming the kit will coat about 12.5 square feet, five kits will be required for the typical job. On this basis, the cost of using the product would amount to about $94.

Contractors currently spray the mats and concrete with the release agent which requires some labor time. They reapply release agent each time the mat is tamped down. If they used the NeverWet instead, they would need to spray the two coatings in the kits the day before the job to ensure the topcoat will cure by the time the job is performed. The labor time for spraying the release agent on both the surface of the concrete and the mats would be greater than the labor time for spraying the mats twice with the two non-stick coatings in the kit. This would allow the stamping job to be completed in a shorter time. To be conservative, however, IRTA assumed the labor requirements for both processes would be the same.

Table 2-4 shows the cost comparison for the release agent and the NeverWet non-stick coating use for the typical stamping job. The results indicate that the cost of using the NeverWet coating is about 9% higher than using the release agent. The price paid by contractors when they purchase release agent can vary and it could be as high as $21 per gallon if the contractor purchases it at a supply store. In that event, the cost of using the release agent would be $105 which is higher than the cost of using the NeverWet coating. Release agent suppliers could also purchase a higher volume of the aerosol cans directly from Rust-Oleum and they would get a lower price than the retail price at Home Depot. This could reduce the cost of using the NeverWet product further and could make this option could be cost effective. In any case, the costs of using the NeverWet coating and the release agent are comparable.

Table 2-4 Cost Comparison for Release Agent and NeverWet Kit for Typical Stamping Job	
Option	**Cost**
Mineral Spirits Release Agent	$86
NeverWet Non-Stick Coating	$94

2.2 Asphalt Manufacture and Application Operations

Asphalt is a heavy, dark brown to black mineral substance, a mixture of hydrocarbons called bitumens. It is found in natural deposits or as a byproduct of the petroleum industry. Most of the petroleum asphalt produced today is used for highway surfacing. The paving material is a dull black mixture of asphalt cement, sand and crushed rock. Asphalt is also used for expansion joints and patches on concrete roads. It is also used on airport runways, tennis courts and playgrounds.

There are two types of asphalt mixes. Hot mix asphalt is commonly used for heavy traffic areas and cold mix asphalt is used for secondary roads or remote locations or maintenance. For hot mix asphalt, the aggregate and asphalt are heated to remove moisture from the aggregate so the material will be fluid for proper mixing and workability. Once the mixing is completed, the hot mix is transported to the paving site and spread in a partially compacted layer to a uniform even surface with a paving machine. While it is still hot, the paving mixture is compacted further by heavy rolling machines. Tractors are sometimes used to move the material and shovels and rakes are used by workers to spread the asphalt to the proper location on the road. Pictures of an asphalt road paving operation in Simi Valley, California are shown in Figures 2-16 through 2-18.

Figure 2-16 Simi Valley Workers Applying Asphalt

The asphalt becomes very sticky over time as it is worked. A release agent is used to ensure that the asphalt does not stick in layers to the applications equipment including the tractor scoops, the shovels and rakes.

The release agent used by virtually all operations is diesel fuel which is a VOC as determined by many VOC test methods including U.S. EPA Method 24. Some VOC regulations exempt diesel and other relatively

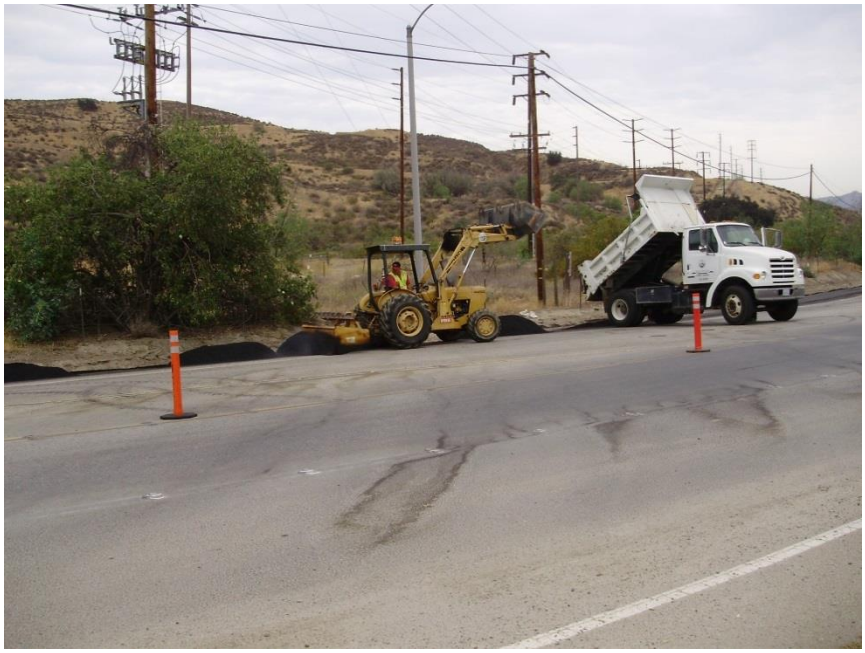

Figure 2-17 Truck Dumping Asphalt for Application in Simi Valley

Figure 2-18 Truck Dumping Asphalt for Application in Simi Valley

heavy hydrocarbons in storage rules because of its low volatility. However, in an application where the diesel is exposed to the open atmosphere, often at elevated temperatures, it is expected that the diesel will eventually evaporate into the atmosphere, contributing to ozone formation. An MSDS for a typical diesel fuel is shown in Appendix A. The diesel fuel evaporates fairly quickly and is reapplied as needed.

There are three different types of facilities that use diesel fuel release agents for asphalt operations. The first type is asphalt manufacturing plants. These plants spray the release agents on some of the plant equipment used in the manufacturing operation. The second type is cities and counties. These facilities generally maintain the roads in their jurisdiction on an ongoing basis. The third type is private contractors involved in asphalt operations. These contractors are hired by homeowners, private companies and government agencies to perform asphalt work. Almost all of the Cal/Trans work in California, for example, is performed by private contractors. The testing and cost analysis for each type of facility is described below.

2.2.1 Asphalt Release Agent Tests with Escondido Asphalt

Escondido Asphalt is a small family owned and run business located in Escondido, California with an average asphalt production level of about 200 tons per hour. The plant is a hot mix plant and the company pioneered the use of a lower temperature process and is committed to keeping the environment clean. Pictures of the plant are shown in Figure 2-19 and 2-20.

Figure 2-19 Escondido Asphalt Manufacturing Plant

The company currently uses diesel fuel as a release agent in the plant and the Plant Manager has been testing alternative release agents over a several year period. The company would like to find an alternative that has a higher flash point. Escondido Asphalt uses the diesel fuel at the end of each day for loosening the asphalt in the mixer drum and on the metal drag slat conveyor. The next morning, when the company starts up the process, the buildup of asphalt, loosened by the release agent, is pulled out. The company also routinely uses diesel fuel on their truck beds and shovels.

The company recently tested two products as alternative release agents and they both worked well. The recycled vegetable oil is supplied by Promethean Biofuels and it has a VOC content of less than 10 grams per liter. This is the same material IRTA tested as a release agent for concrete stamping and the MSDS for the product is shown in Appendix A. This material has a relatively high flash point and, because of that, the company has decided to adopt it rather than the other successfully tested alternative which has a lower flash point and higher VOC content.

Figure 2-20 Processing Asphalt at Escondido Asphalt

2.2.2 Release Agent Alternatives Cost Analysis for Escondido Asphalt

Escondido Asphalt uses about 15 gallons per day of diesel fuel as a release agent. Assuming the plant operates 260 days per year, the annual use amounts to 3,900 gallons. The current cost of the fuel is $4.25 per gallon so the cost of using the diesel fuel amounts to $16,575 per year.

The alternative recycled vegetable oil alternative is more costly than the diesel fuel. The company would purchase the alternative in totes and the price per gallon for totes is $5.75 per gallon. On this basis, if the same amount of the vegetable oil is required, the annual cost would be $22,425.

Table 2-5 shows the cost comparison for the diesel fuel and the recycled vegetable oil. The figures show that the cost of using the recycled vegetable oil is 35% higher than using the diesel fuel.

Table 2-5
Annual Cost Comparison for Release

Release Agent	Annual Cost
Diesel Fuel	$16,575
Recycled Vegetable Oil	$22,425

2.2.3 Asphalt Release Agent Tests with Simi Valley

IRTA identified this type of operation as another instance where release agent is used while working with the City of Simi Valley on another project. The City uses diesel fuel as a release agent for the application equipment, like shovels and tractors, which are used to apply the asphalt to roads in their jurisdiction.

IRTA conducted initial testing of a petroleum based release agent made by Dodge Oil for concrete stamping. Pictures of this initial testing are shown in Figures 2-21 and 2-22. The results of the initial field testing were promising. IRTA worked with Dodge Oil to find formulations more appropriate for the asphalt industry. The release agents used in concrete stamping generally contain a fatty acid to react with the alkaline concrete. In the case of asphalt, this fatty acid is not needed.

Figure 2-21 Spraying Release Agent on Tractor

Figure 2-22 Spraying Release Agent on Tractor Scoop

IRTA conducted scaled-up field testing of two different low volatility petroleum products for this application. MSDSs for the two alternatives, called Holly 70 and Bango 250, are shown in Appendix A. IRTA also offered to provide two vegetable based alternatives for testing but Simi Valley indicated they had tested soy based products in the past and that none of them worked well.

The City tested the two alternative products on several asphalt jobs. The results indicated that the Holly 70 is similar to the diesel fuel. It sprays well but doesn't last as long as the Bango 250 material when applied to the tools. The Bango 250 product is thicker than the Holly 70 product and it is more difficult to spray. The City indicated it doesn't stick to the tools and seems to be effective as a release agent. The City workers indicated that they did not think either product worked as well as diesel. The City is currently conducting tests on a blend of the two different products to see if they can optimize the advantages of each. They agreed to test the recycled vegetable oil used successfully by Escondido Asphalt and that testing is also underway.

2.2.4 Release Agent Alternatives Cost Analysis for Simi Valley

Simi Valley purchases between 100 and 200 gallons of diesel fuel per year for their operations. For purposes of analysis, IRTA assumed the City would purchase 150 gallons per year. IRTA assumed the current price of diesel fuel which is about $4.25 per gallon. Holly 70 and Bango 250 are priced at $8.70 and $8.20 per gallon respectively if they are purchased in drum quantities. If purchased in three or more five gallon pails, the prices are higher, $11.70 and $11.20 per gallon respectively.

IRTA analyzed the cost assuming the City would purchase the alternatives in drums. The two alternatives have lower volatility than diesel so less of them may be required. To be conservative, IRTA assumed that the same amount of each of the alternatives would be required. Table 2-6 below summarizes the cost comparison. The figures show that the cost of using the Bango 250 is 48% higher than the cost of using diesel.

Table 2-6
Annual Cost Comparison for Release Agents at Simi Valley

Release Agent	Annual Cost
Diesel Fuel	$638
Holly 70	$1,305
Bango 250	$1,230

2.2.5 Asphalt Release Agent Tests with Asphalt and Grading Paving Company

This company is a private contractor who offers asphalt services. In this case, the company was hired by another company, Roto Rooter, who was installing a sewer line along a large length of a street. After the sewer was installed, Asphalt Grading and Paving Company poured the asphalt to surface the road. The company routinely uses diesel fuel as a release agent on the asphalt application equipment.

IRTA provided two vegetable based alternatives to the company for testing. One of these is the WD 40 lubricant described earlier and tested for concrete stamping. The second is the recycled vegetable oil made by Promethean Biofuels which was also tested for concrete stamping and by Escondido Asphalt. Although both materials functioned well, the company much preferred the recycled vegetable oil product. They used

it during the entire day on the truck liftgate, on wheel barrows used to transport the asphalt from the truck to the appropriate location on the street and on the shovels and rakes they used to smooth the surface of the asphalt. Pictures of the operation during the testing are shown in Figures 2-23, 2-24 and 2-25. The workers indicated they liked the recycled vegetable oil much better than the diesel fuel they use currently and were interested in converting to the product.

Figure 2-23 Release Agent Testing on Truck Liftgate

Figure 2-24 Release Agent Testing on Shovel

Figure 2-25 Release Agent Testing on Wheel Barrow

2.2.6 Release Agent Alternatives Cost Analysis for Asphalt and Grading Paving Company

For the cost analysis, IRTA assumed that the company pays the same price as Simi Valley for the diesel fuel, $4.25 per gallon. The company indicates they use about 50 gallons per month or 600 gallons per year of the fuel. IRTA assumed the contractor would purchase the alternative in drum quantities. WD 40 indicates the cost of their vegetable based lubricant if purchased in drum quantities would be $24.84 per gallon. The cost of the recycled vegetable oil is much lower, at $6.90 per gallon when purchased in drums.

Both the recycled vegetable oil and WD 40 have lower volatility than diesel so less of them could be required. To be conservative, IRTA assumed that the same amount of the alternatives would be necessary. On this basis, Table 2-7 presents the results of the cost comparison. The figures show that the cost of using the low-VOC recycled vegetable oil would be higher by 62%. The cost of using the WD 40 would be significantly higher than the cost of using the diesel fuel.

Table 2-7
Annual Cost Comparison for Release Agents at Asphalt and Grading Paving Company

Release Agent	Annual cost
Diesel Fuel	$2,550
WD 40 Product	$14,904
Recycled Vegtable Oil	$4,140

III. Manufacturing Operations Using Molds

3.1 Manufactured Parts Molding and Cleaning

Parts made of various substrates are molded into a desired shape in many different types of manufacturing facilities. In general, the process involves fabricating a master mold with a shape of the parts that are required, applying a mold release agent to the surface of the mold, applying the substrate material to the mold, curing the material and removing it from the mold. The purpose of the release agent is to ensure that the substrate material will not stick to the mold and that the molded part can be removed easily.

In general, mold release agents are composed of a small amount of resin material and a carrier. The carrier evaporates, leaving the resin material as a smooth surface on the mold. The carrier is sometimes water but, more often, it is a solvent. The solvents used most widely for this purpose are mineral spirits.

In many molding operations, the mold release agent is applied several times to the mold. This is not because several layers of the resin are needed on the mold. Rather, it is because it is important to deposit the resin on every part of the mold. The master molds are used over and over to make parts and, if a part sticks to the mold, the mold may be destroyed or damaged and it is expensive and time consuming to make another mold.

There are three types of mold release agents. The first type is a wax mold release agent which is applied with cloths. Wax release agents were used historically for fiberglass parts molding, which is a significant portion of the market. They are forgiving because it is easier to ensure they have been applied on all parts of the mold. They do leave a residue after the part is made, however, so the surface of the mold needs to be cleaned before more parts are made. In general, the wax mold release agent is applied each time a part is made; in a few cases, two parts may be fabricated with one wax mold release application.

Most companies have converted to the second type of release agent, liquid mold release agents which are also called semi-permanent mold release agents. Similarly to the wax mold release agents, several coats of the liquid agent are applied to the mold. Multiple parts can be made with one application of the release agent and this reduces the labor requirements and therefore the cost. The molds do not have to be cleaned or can be cleaned very lightly when liquid mold release agents are used.

The third type of release agent is an internal mold release agent which is most often used for parts made of polymers of all kinds and frequently is used in compression molding operations. In this case the mold release agent is added to the polymer, the material of construction of the part. No carrier solvent is used in this type of operation.

IRTA worked with companies that make parts from a variety of substrates to test alternative low-VOC mold release agents. The companies that participated in the project used wax, liquid and internal mold release agents. IRTA worked with a few of the companies in the project to test alternative low-VOC cleaners and cleaning methods. These included two companies using wax mold release agents and one company that needs a cleaning agent to remove a mold protectant from metal molds used in their process. The detailed description of the alternatives testing is described below for each of the participating facilities. One of the companies, a boat manufacturer, elected to remain anonymous.

3.2 Anonymous Boat Manufacturer

This boat manufacturer is located in Southern California and each year the company manufactures about 200 sailboats that are 26 feet long. The boats are made of fiberglass and, as part of the process, the hulls of the boat and a number of other boat parts are molded. Like other yacht manufacturers, the company uses single sided female molds made from fiber reinforced plastic to make the hulls. The mold is made by taking the reversal of a male pattern. The company uses the traditional method for making fiberglass parts. During the process, the release agent is first applied to the mold and then a layer of gelcoat is applied. The gelcoat is left for a few hours to harden. Once the gelcoat hardens, a spray gun is used to deposit the fiber resin mixture on the surface of the mold. When the material is sprayed on the mold, brushes or rollers are used to remove any trapped air and to make sure there is good wetting of the fiber. Fabric layers are added into the laminate and the resin is cured at room temperature for several hours. After curing, the part is removed from the mold. IRTA worked with the boat manufacturer as part of the project to test alternative mold cleaning agents and alternative mold release agents.

3.2.1 Alternative Mold Cleaning Tests

The company uses a wax based mold release agent and the wax and perhaps some gelcoat residue builds up and needs to be cleaned from the mold periodically. The molds are currently cleaned with styrene, a component of the gelcoat used in the fiberglass layup process. An MSDS for the material is shown in Appendix B. The styrene is wiped on the mold with a saturated cloth and allowed to soak for a period of time. A stiff barbecue brush is used with the styrene to aid in the removal, particularly on areas that are referred to as non-skid. These are areas where the wax/gelcoat buildup is the greatest because these areas on the part, shown in Figure 3-1, have blind holes. The buildup is particularly difficult to remove for non-skid parts and scrubbing with the brush vigorously is necessary for complete removal. IRTA tested a wide range of materials as alternative cleaners for the wax buildup on the molds. The particular focus was on the non-skid portion of the molds.

Figure 3-1 Non-Skid Area on Mold

3.2.1.1 Water Based Cleaning Alternatives

In other applications which do not involve molding, water-based cleaners are often used to remove buffing compound or wax from parts. In general, however, these cleaners are used in a cleaning bath and are heated to 160 to 180 degrees F which helps to melt the buffing compound or wax. In addition, the cleaners are generally paired with either very high pressure spray or ultrasonics, which function as strong agitation methods for enhancing the removal. In the case of molding operations, particularly where there are large molds, this approach would be impractical because it would require a very large system and would be extremely expensive. As a result, in this application, IRTA tested the alternatives using hand cleaning, unheated but with agitation.

Four different categories of water-based cleaners and seven water-based cleaners in all were tested using the same type of brass barbecue brush the company currently uses with the styrene. The cleaners included two alkaline cleaners, a neutral cleaner, two acidic cleaners and two cleaners containing pumice abrasive. None of these cleaners was successful in removing the residue from the non-skid material of the molds. In the case of the alkaline cleaners and the acidic cleaners, tests using a high pressure Hotsy spray system were also conducted. This did not improve the cleaning.

3.2.1.2 Solvent Cleaning Alternatives

A variety of low-VOC or non-VOC chemicals and blends of the cleaners were tested to see if they could effectively remove the wax/gelcoat buildup. IRTA tested a soy based cleaner with a heavy surfactant additive. The VOC content of the soy based cleaner has been determined by the District to be less than 25 grams per liter. IRTA also tested acetone and propylene carbonate and various blends of the soy based cleaner and these two chemicals. Acetone and propylene carbonate are exempt from VOC regulations. These materials did not successfully remove the residue from the molds. IRTA also tested another exempt chemical, PCBTF, for cleaning the molds and this cleaner was effective in removing the wax buildup. A picture of the cleaning tests with PCBTF is shown in Figure 3-2 and an MSDS for the solvent is provided in Appendix B.

Figure 3-2 Cleaning Test of PCBTF at Boat Manufacturer

3.2.1.3 Cleaning Alternatives Testing

IRTA provided larger quantities of the PCBTF cleaner to the company for longer-term testing. The cleaner was used in the same manner as the styrene. It was applied and allowed to work for a time and then brushed vigorously into the pores of the non-skid area with the brass barbeque brush. The cleaner worked very well and was effective in removing the buildup. During the testing, parts were molded after cleaning with the PCBTF and there were no production problems.

3.2.1.4 Cost Analysis of Alternative Cleaner

The supervisor at the boat manufacturing facility indicated that the workers used about the same volume of the alternative as they did the styrene during the testing. He also indicated that no additional labor was needed in using the alternative solvent. In 2012, the company purchased 15 gallons of styrene for the cleaning task. The cost of the styrene is $83.35 per five gallons. A supplier of the alternative solvent, PCBTF, indicates that he would provide the solvent at $265 per five gallon pail. The PCBTF is more expensive than styrene. Table 3-1 provides the annual cost comparison for using the two cleaners under the assumption that 15 gallons of each would be required. The values indicate that the cost of using the alternative cleaner is more than three times higher than the cost of using the styrene.

Table 3-1
Annual Cost Comparison of Cleaners for Boat Manufacturer

Cleaner	Purchase Cost
Styrene	$250
PCBTF	$795

3.2.1.5 Process Change Alternatives

There are two other options for changing the cleaning process without using a liquid cleaning alternative. The first option is for the boat manufacturer is to convert from the wax mold release agent to an alternative liquid mold release agent. As discussed earlier, one advantage of using the liquid mold release agent is that more parts can be made in the mold without reapplication of the mold release agent. A second advantage is that companies who use liquid mold release agents do not have the same cleaning needs as the companies using wax mold release agents. They can do minimal cleanup using an exempt solvent like acetone (see KF Fiberglass later in this section). As discussed later, IRTA did test alternative liquid release agents with the boat manufacturer and they worked effectively.

The second option is to use a polishing compound to remover the buildup from the wax mold release agent on the mold. The polishing compound will buff the surface and make it acceptable to accept a new application of mold release agent. Although this option was tested effectively, IRTA did not analyze it further.

3.2.2 Alternative Mold Release Agent Testing

As discussed above, semi-permanent or liquid mold release agents offer an advantage over wax mold release agents in that more parts can be made in the mold without reapplication of the release material. Some companies are very conservative and they have used wax mold release agents for many years. These wax release agents are more forgiving than liquid release agents and the companies still using them are

concerned that a conversion to the liquid materials might allow for mistakes that could destroy a mold. Molds are very expensive so companies avoid changing the process in any way so the parts they make will be guaranteed to release from the mold. The wax mold release agents are generally reapplied before making each part; in some cases, two parts might be molded with one application. An MSDS for the wax mold release agent used by the boat manufacturer, called M08-Mold Release Paste Wax, is shown in Appendix B.

IRTA tested alternative low-VOC mold release agents with the boat manufacturer. Both were liquid mold release agents; one was a water-based material and the other was formulated with PCBTF, an exempt solvent, specifically for testing during this project. An MSDS for the water-based mold release agent, called Kantstik Aqua Release, is shown in Appendix B. An MSDS for the solvent, PCBTF, is also shown in Appendix B.

IRTA conducted testing with a mold release agent supplier, Specialty Products Company (SPC), to develop the new solvent based mold release agent. SPC provided the resin material and IRTA formulated various carriers composed of exempt and low-VOC materials, to find one that would be soluble in the existing resin and have an appropriate evaporation rate. The aim was to find an alternative mold release agent with a VOC content of no more than 25 grams per liter. No other solvent blends satisfied these requirements although other carriers with a VOC content greater than 25 grams per liter could be used.

3.2.2.1 Cost Analysis of Alternative Mold Release Agents

The boat manufacturer makes about 200 boats per year. In a recent year, the company purchased 300 11 ounce cans of the wax mold release agent to use in molding the boat hulls and other parts for the 200 boats. The cost of each can is estimated by the supplier at between $8 and $9; assuming the midpoint, the annual cost of purchasing the mold release material is $2,550.

The workers at the boat manufacturing facility apply several coats of the mold release agent when making a mold. As discussed earlier, this ensures that all parts of the mold are coated with the resin, the active ingredient. The boat manufacturing supervisor estimates that the labor used to apply mold release agent is 1.5 hours per day. Assuming a five day work week and 52 weeks per year, this amounts to 390 labor hours per year. At a labor rate of about $10 per hour, the mold release related labor cost is $3,900 per year.

Table 3-2 shows the cost to the boat manufacturer of using the wax mold release agent. The values show that the major cost component of the mold release process is the labor cost. The total cost of using the baseline wax mold release agent is $6,450 per year.

Table 3-2
Annual Cost of Using Wax Mold Release Agent for Boat Manufacturer

Cost Component	Cost
Mold Release Agent Cost	$2,550
Labor Cost	$3,900
Total Cost	$6,450

IRTA tested the two alternative low-VOC mold release agents with the boat manufacturer. Both of these release agents worked well for making multiple parts and four parts were made with each release agent without reapplying the mold release. A picture of the part used for testing for the water-based mold release

agent is shown in Figure 3-3 and a picture of the part used for testing the PCBTF mold release agent is shown in Figure 3-4.

Figure 3-3 Part Made with Water-Based Mold Release Agent

Figure 3-4 Part Made with PTBCF Mold Release Agent

For the cost analysis, IRTA assumed that more parts could be made with the alternative liquid release agent and that more square footage of the parts could be covered with an equal volume of release agent. As discussed earlier, 300 cans containing 11 ounces of product or about 206 pounds of the wax release agent are used currently. Assuming a density of seven pounds per gallon, the volume of agent needed is 29.43 gallons annually. IRTA assumed that four parts could be made with the water-based liquid release agent for every one part made with the wax release agent and that the same volume of the liquid release agent would

get 50% more coverage. Thus for every part made with the wax release agent, the same volume of liquid release agent could make six parts. For the water-based material and PCBTF material, this implies that 4.90 gallons of the alternative agent would be necessary annually. The supplier indicates that the cost of the water-based mold release agent is $61 per gallon. The total annual cost of this mold release agent is $299 annually. The supplier estimates that the cost of the zero VOC PCBTF mold release agent would be $120 per gallon for a total annual cost of $588.

The biggest advantage of using a liquid mold release agent instead of a wax mold release agent is that the mold can be used to make multiple parts without reapplication of the mold release agent. In general, the worker still applies multiple coats of the mold release agent, again to ensure that all parts of the mold are covered with the release agent. The labor used in the application of the liquid mold release agent is likely to be the same as the labor used in the application of the wax mold release agent. Because multiple parts can be made with one application of the liquid, however, the total labor required would be much less. In the case of the testing at the boat manufacturer, four parts were made with the two alternative liquid mold release agents. Assuming this could be done for all parts, the labor requirement would be reduced from 390 to 97.5 hours per year.

The supervisor at the boat manufacturing facility indicated that the parts made using the two alternative mold release agents were a little streaky and not perfect and it was necessary to buff them after they were released from the mold. The increased labor for this activity is estimated to be no more than about 30 minutes per day and is likely to be much less. Assuming the increased labor for the post buffing, the total labor for mold release agent activities is 130 hours per year. The total labor hours required for the liquid mold release agent would be 227.50. Again, assuming a labor rate of $10, the labor cost would amount to $2,275 per year.

When a company converts from a wax mold release agent to a liquid release agent, there is a learning curve on how to optimize application of the new agent. The workers at the boat manufacturing plant had not yet learned how to best apply the material and this is the reason for the post buffing requirement. As the workers learned better application methods, there would eventually be no need for post buffing. To be conservative, however, IRTA assumed that all parts would require post buffing for the cost analysis.

Table 3-3 shows the annual cost comparison for the wax mold release agent and the two alternative low-VOC mold release agents. The results show that the lowest cost option is use of the water-based mold release agent. The cost of using the zero VOC PCBTF mold release agent is also less than the cost of using the wax high-VOC mold release agent. The cost of using the water-based mold release agent is 41 percent lower than the cost of using the wax mold release agent and it is the lowest cost option.

Table 3-3
Annual Cost Comparison for Liquid Mold Release Agents for Boat Manufacturer

Cost Component	Wax Mold Release Agent	Water-Based Mold Release Agent	PCBTF Mold Release Agent
Mold Release Agent Cost	$2,550	$1,510	$2,207
Labor Cost	-	$2,275	$2,275
Total Cost	$6,450	$3,785	$4,482

Much of the cost reduction that can be achieved by the boat manufacturer is attributable to the fact that the labor cost is lower for companies using a liquid mold release agent in place of a wax mold release agent. For comparative purposes, IRTA wanted to estimate the annual cost of using a high VOC liquid mold release agent. The agent supplier estimates that a typical high-VOC content agent is priced at about $100 per gallon. Assuming that 4.90 gallons of this release agent would be required, the annual cost of the agent is $490. This cost is higher than that of the water-based release agent and is lower than the cost of the PCBTF release agent.

3.3 FinCo Company

FinCo Fabrication is located in Southern California and the company has manufactured fiberglass products for more than 15 years. FinCo is a jobshop and the products the company manufactures range from concert speakers and forklift bodies to shower facilities for corporate jets. The company works with a variety of industries including trucking, chemicals, housing construction, entertainment and boat building.

When a customer approaches FinCo, the company uses an open molding process by developing the most practical and cost effective method for fabricating the product. The tooling department manufactures production molds from blueprints or a master copy of the product. The employees then create one or more precision molds that reproduce the part throughout the manufacturing process. FinCo either works from the customer's production mold or develops molds that customers can use for their own production processes. After the molds are prepared, the company begins fabricating the product using fiberglass composites.

3.3.1 Alternative Mold Release Agent Testing

For several years, FinCo has used wax mold release agent for fabricating the parts. In general, as with other wax mold release agents, the release must be reapplied for each part. The advantage of the wax mold release agent is that they are more forgiving than liquid mold release agents; the workers are familiar with them and they are easier than liquid mold release agents to use to get complete coverage of the mold. The wax is visible on the mold whereas the liquid resin is not. With liquid mold release agents, however, more parts can be fabricated without reapplication of the agent.

IRTA tested an alternative low-VOC water-based mold release agent with FinCo. In general, the liquid release agents contain a carrier material, in this case water, which evaporates during application leaving the resin material which provides a slick surface on the mold so the part does not stick. Three to five applications of the liquid release agent are common to ensure that there is full coverage of every part of the mold. Several parts can then be molded before the workers need to reapply the mold release agent. This water-based mold release agent, called Kantstik Aqua Release, is the same release agent tested at the anonymous boat manufacturing facility. FinCo made two parts without reapplying the water-based release agent. A picture of these parts is shown in Figure 3-5.

3.3.2 Cost Analysis of Alternative Mold Release Agent

FinCo purchases the wax mold release agent used in the process in cases which contain 12 cans each of the wax based material. In recent years, the company has purchased about one case every two months. Each of the cans contains 14 ounces of material and the cost is $8.35 per can. The total amount of mold release agent used is 63 pounds or nine gallons per year assuming a density of seven pounds per gallon. FinCo's total cost for purchasing the mold release agent is $601 annually.

Figure 3-5 Parts Made with Water-Based Mold Release Agent at FinCo

FinCo made two parts with the liquid mold release agent; the company may have been able to make additional parts without reapplication but this was not tested. For the cost analysis, IRTA made the conservative assumption that two parts could be made without reapplication for the liquid release agent and one part could be made with the wax mold release agent. To also account for the 50% greater coverage of the parts with the liquid release agent, IRTA assumed that the same volume of liquid release agent could be used to make three parts instead of one part with the wax release agent. On this basis, assuming that three gallons per year of the water-based release agent would be used at a cost of $61 per gallon, the total purchase cost for release agent would be $183.

A company representative estimates that the FinCo workers may apply mold release agent for two hours each day. Based on an eight hour work day and a five day work week, the labor hours for applying release agent amount to 520 per year. Assuming an average labor rate of $20, the labor cost is $10,400 per year. The workers, in this case, did not indicate that post buffing labor was needed for the parts made with the water-based release agent. If the company converted to the water-based mold release agent, the labor cost would be half this value or $5,200 annually.

Table 3-4 shows the annual cost comparison for FinCo for using the wax and the liquid mold release agents. The values of the table show that the cost of using the water-based mold release agent is less than half the cost of using the wax mold release agent. If more than two parts could be made with the alternative release agent without reapplication, the cost of using the water-based mold release agent would be even lower.

Table 3-4
Annual Cost Comparison of Mold Release Agents for FinCo

Cost Component	Wax Mold Release Agent	Water-Based Mold Release Agent
Mold Release Agent Cost	$601	$183
Labor Cost	$10,400	$5,200
Total Cost	$11,001	$5,383

3.4 KF Fiberglass

KF Fiberglass is a small company with seven employees located in Downey, California. The company makes fiberglass parts and specializes in recreational vehicle (RV) parts. KF is a jobshop and has the capability to design and manufacture molds with their own tooling department. The types of products made by KF include front caps and rear caps for motorhomes, trailers and buses, replacement parts for RVs and trailers, wind deflectors for trucks, planters for malls and college campuses, science laboratory wet tables, showers and counter tops.

3.4.1 Alternative Mold Release Agent Testing

When IRTA began working with KF Fiberglass, the company was using a high VOC content wax mold release agent exclusively for all of their parts. A picture of the RV parts is shown in Figure 3-6. During the project, the company converted first to a liquid release agent exclusively and, later, to a liquid release agent for most parts and a wax release agent for some parts. IRTA wanted to test a water-based mold release agent with the company but, the company could not devote the time to the testing.

Figure 3-6 RV Part at KF Fiberglass

3.4.1 Cleaning Alternatives Testing

Some of the RV parts, like those at the anonymous boat manufacturing facility, had non-skid areas that are difficult to clean. IRTA tested a variety of alternative cleaning materials with the company before the conversion to the liquid release agent. These included water-based cleaners, acetone, acetone blends and soy based cleaners. None of these cleaners worked effectively. The company converted exclusively to the liquid release agent and verified that acetone could be used for any cleaning needs that remained. When the company converted back to a wax mold release agent for some of the parts, the company needed to clean non-skid areas of the parts again. Like the anonymous boat manufacturer, this company uses styrene as the cleaning agent.

IRTA had completed the scaled-up cleaning tests with the anonymous boat manufacturer and found that PCBTF was an effective cleaner for the non-skid areas. KF agreed to test the alternative and IRTA provided larger quantities of the PCBTF to the company. Over a several month period, the company apparently could not devote the time to the testing.

3.5 Foam Molders

Foam Molders, located in Cerritos, California, was established in 1971. In their 150,000 square foot facility, the company offers engineering, molding and fabrication of flexible and rigid foam. Foam Molders is a leader in molding polyurethane foams. Much of the work involves thermoforming where the molds are heated during the forming process.

The company makes original molds in the research and development shop and runs production in a larger operation. The original molds include parts for Mister Potato Head and palm leaves. The production parts range from various types of packaging used by medical instrument companies to engine plug covers for protecting aircraft engines during repair.

The company agreed to work with IRTA only in a limited way. Some of the mold release agents used in the production molding are water-based and many are high VOC materials. The company did not provide information on the use of the release agents so no cost analysis could be performed.

IRTA did conduct some testing with the company on two sets of parts. IRTA tested a water-based mold release agent and the low-VOC PCBTF release agent developed for this project on one part. Three coats of the release agent were applied to a mold the day before the testing. The part that was tested is made of a polyurethane foam that is self skinning. One part was made with each of the molds with the different release agents. When a second part was molded, the part with the water-based mold release stuck to the mold. The second part with the solvent based mold release was made successfully.

At a later time, another set of two parts were made successfully with the low-VOC solvent based mold release. Pictures of the parts made with the alternative mold release agent are shown in Figures 3-7 and 3-8.

3.6 M.C. Gill

M.C. Gill develops and manufactures high performance composite products for the commercial aircraft and aerospace industries. The company is known for cargo liners used in air freighters and baggage compartments. The floor panels and interior panels manufactured by M.C. Gill are standard on many aircraft.

One specific part made by M.C. Gill is a phenolic impregnated decompression panel for aircraft which is designed to fail at a particular pressure in an emergency. Two of the panels are made simultaneously in a mold using a mandrel. The company currently uses an aerosol mold release agent with a high VOC content in the molding operation.

Figure 3-7 Long Part Made with Mold Release Agent at Fold Molders

Figure 3-8 Flat Part Made with Mold Release Agent at Fold Molders

3.6.1 Alternative Mold Release Agent Testing

An MSDS for the aerosol mold release agent currently used in the process is shown in Appendix B. The product, called HMT(R)-2 Frekote (R) Hot Mold Touchup, comes in aerosol cans that weigh 9.7 ounces. It contains a resin, the active ingredient of the mold release agent, a VOC solvent carrier and a propellant.

IRTA worked with M.C. Gill to test alternative low-VOC mold release agents for molding the decompression panels. IRTA tested two water-based alternatives with the employees who operate the molding machine.

The first water-based alternative that was tested was an aerosol product. The testing of this material did not result in acceptable results. The second product, a liquid release agent called Kantstik Aqua Release, worked well; this is the same water-based material tested earlier with the anonymous boat manufacturer and FinCo.

IRTA worked with the M.C. Gill employees on several different occasions, sometimes for several hours, to test the alternative water-based mold release. Many parts and multiple parts successively were made with the release which was generally applied with a cloth rather than spraying. There is no reason that the material could not be sprayed on the mandrel and mold with a spray bottle or a pump sprayer for convenience. The parts that were made with the alternative mold release material were judged to be acceptable by the supervisor. A picture of the molding machine used to make the panels is shown in Figure 3-9. Figure 3-10 shows the machine being prepared for the molding. Each cycle of the machine requires about 30 minutes to cure the parts at a temperature of about 300 degrees F.

Figure 3-9 Molding Machine at M.C. Gill

When the parts, which are still hot, come out of the mold, the employees cool them in a room temperature water bath, shown in Figure 3-11, for 10 to 20 minutes. The large panel is cut in half with a blade to make two parts. The parts made in the molding operation are shown in Figure 3-12.

The employees generally reapply the solvent mold release agent each time a set of parts is made. In a few cases, more than one set of parts was made with one application of the water-based mold release. This suggests that less of the water-based mold release could be required if the company converted to the alternative.

3.6.2 Cost Analysis of Alternative Mold Release Agent

M.C. Gill indicates that about 48 cans of the aerosol mold release agent are used in a five week period. Generally speaking, the VOC propellant represents about 10 percent of the total weight of the can. On this basis, about one ounce of the 9.7 ounce can is propellant and 8.7 ounces are the resin and solvent carrier.

Figure 3-10 Preparing Molding Machine at M.C. Gill

Figure 3-11 Water Bath at M.C. Gill

Figure 3-12 Parts Made in Molding Operation at M.C. Gill

Assuming 52 weeks in a year, 499 cans of the aerosol material are used and the weight of product, excluding the propellant, that is required to make the decompression panels is 271.44 pounds per year.

M.C. Gill does not provide the company's cost of the high-VOC aerosol product as a matter of policy. The product supplier provided generalized costs to IRTA for the analysis. The distributor indicates that the price ranges from $14.17 to $12.97 per can if the user purchases one or two cases respectively. A case is 12 aerosol cans. Distributors do have discretion, however and can give good customers a much lower price, as low as $10 or $11 per can. To be conservative, assuming the lowest price of $10 per can, M.C. Gill pays $4,990 per year for the mold release agent.

The same weight of the alternative mold release agent would be required to make the same number of parts the company makes currently. The alternative water-based mold release agent is sold in liquid form rather than in aerosol cans. The supplier indicates that the product is sold in cases which contain four gallons of the product. Assuming the product has a liquid density of 8.33 pounds per gallon, each case contains 33.32 pounds of mold release agent. M.C. Gill would use 8.15 cases of the alternative mold release agent per year. The cost of the water-based mold release agent, according to the supplier, is $252.25 per case. On this basis, the total annual cost of the water-based mold release agent is $2,056.

Table 3-5 summarizes the cost of using the current and alternative mold release agents. The values show that the company could reduce their cost by 59 percent by making the conversion to the water-based mold release agent.

Table 3-5
Annual Cost Comparison of Mold Release Agents for M.C. Gill

Cost Component	Aerosol Mold Release Agent	Water-Based Mold Release Agent
Release Agent Cost	$4,990	$2,056
Total Cost	$4,990	$2,056

3.7 Oldcastle Precast

Oldcastle Precast is a leading manufacturer of precast concrete, polymer concrete and plastic products in the U.S. The company has more than 80 locations and 3,000 employees. The company manufactures a range of concrete products including utility vaults, reinforced concrete pipe, catch basins, drainage and septic tanks, retaining walls, storm shelters, wall panels, concrete barriers and supports used in pier construction.

IRTA worked with the Oldcastle Precast plant in Fontana, California. The company uses a hand pump sprayer to spray a mold release agent into the steel forms that are used to form the concrete parts. An MSDS for the release agent, called Grifcote FR-S-VOC, is shown in Appendix B. It contains 90 to 98 percent petroleum distillate. This mold release product contains less than 250 grams per liter and the release supplier indicates that it complies with the VOC limit for form releases in SCAQMD Rule 1113 "Architectural Coatings.

3.7.1 Alternative Mold Release Agent Testing

IRTA worked with the company to test alternative release agents. IRTA had done preliminary testing of some alternatives in the concrete and concrete overlay stamping operations described earlier. In those tests, three alternatives worked well. These included a Dodge Oil petroleum lubricant product, a WD 40 soy oil product and PCBTF. For the Oldcastle operation, IRTA decided to test the same Dodge Oil and WD 40 products tested for concrete stamping and the PCBTF product IRTA formulated with SPC. IRTA made a decision to test the SPC product instead of plain PCBTF in this application because it contained a resin which could be necessary for releasing the parts from the steel forms. MSDSs for the Dodge Oil Product and WD 40 were shown in Appendix A. IRTA also decided to test propylene carbonate because it is exempt from VOC regulation even though it did not release the concrete in the concrete stamping applications as cleanly as the other alternatives.

For the comparative tests, the Engineering Manager at Oldcastle provided five round steel supports that were roughly six inches in diameter and one foot long with a removable bottom. A picture of these testing devices is shown in Figure 3-13. The currently used release agent and the four alternative agents were applied to the inside and bottom of the devices. The concrete was allowed to cure overnight. The plant staff removed the bottoms of the devices to examine the concrete with IRTA the next day. A picture of the staff removing the concrete from the devices is shown in Figure 3-14.

All five of the concrete parts released from the molds. The propylene carbonate part was more difficult to remove than the others. This is consistent with the findings in concrete stamping. In addition to not releasing well for the Oldcastle concrete, the finish of the propylene carbonate part was not as good as that of the other parts. It had several "bug holes" which are air holes on the outside of the concrete part that make it look non-uniform.

The three best looking parts were the part made with the currently used release agent and the parts made with the PCBTF release agent and the WD 40 release agent. The part made with the Dodge Oil product was slightly more difficult to release but it also performed adequately. All three of these materials could be considered as reasonable alternatives in this application.

Figure 3-13 Testing Devices at Oldcastle Precast

Figure 3-14 Removing Concrete from Testing Devices at Oldcastle Precast

Although it was not included in the tests, the plain PCBTF, without the resin additive, would likely have performed well as it did in concrete overlay stamping. Oldcastle paints the parts after the molding operation so the PCBTF bleaching effect observed for colored concrete stamping would not occur here. The plain PCBTF is less costly than the PCBTF resin (see below) so it could be a more viable product.

3.7.2 Cost Analysis of Alternative Mold Release Agents

IRTA conducted a cost analysis for the currently used release agents and the three alternatives that were tested successfully. Oldcastle purchases their release agent in totes and the Engineering Manager indicates that the company uses about 100 gallons per week of the release agent. The cost of the release agent in totes is about $8 per gallon. Assuming the release agent is used 52 weeks a year, the total cost of using the Grifcote agent is $41,600 per year.

The cost of the Dodge Oil petroleum lubricant product with a small amount of fatty acid additive for reacting with the concrete is $8.90 per gallon when the material is purchased in drums or totes. WD 40 does not presently offer their product in totes but the supplier indicates that a drum price would be $1,366 to the distributor. Assuming the distributor would mark the price up 15 percent, the price to the customer would be $28.56 per gallon. The tote price is likely to be lower so, for purposes of analysis, IRTA assumed the customer would pay a drum price with no markup or $24.84 per gallon for purchases in totes. The PCBTF release agent supplier indicates that a tote price would be $86.50 per gallon. The price of this release agent is much higher because it contains a resin; although the cost for this application is high, it is appropriate and competitively priced for parts molding in other applications.

Table 3-6 shows the annual cost comparison for the release agent used presently by Oldcastle and the alternative release agents that were tested. The values show that the cost of using the Dodge Oil product is 11 percent higher than the cost of using the current product. The cost of using the other two products is much higher.

Table 3-6
Annual Cost Comparison of Mold Release Agents for Oldcastle Precast

Release Agent	Annual Cost
Grifcote FR-S-VOC	$41,600
Dodge Oil Product	$46,280
WD 40 Product	$129,168
PCBTF Product	$449,800

As mentioned earlier, the Grifcote release agent used currently has a VOC content that is less than 250 grams per liter. The Dodge Oil product is a lower volatility so it would evaporate less quickly than the Grifcote product. If less of this alternative were required on a large scale, then the annual cost of using the Dodge Oil product might be lower than the cost of using the current material.

3.8 CAMBRO

CAMBRO is currently using an aerosol cleaning product to remove a mold protecting product from the metal molds. The mold protectant, in the form of a dry film, prevents the steel molds from rusting during the time they are not in use. An MSDS for this material is shown in Appendix B. When the molds need to be used, employees spray them with an aerosol cleaning formulation which contains hexane and a propellant. An MSDS for the cleaner is shown in Appendix B. The hexane is sprayed on the molds and the employees use toilet tissue, a gentle cleaning material which will not scratch the molds, to wipe the excess solvent and mold protectant from the parts. A picture of one of the molds is shown in Figure 3-15.

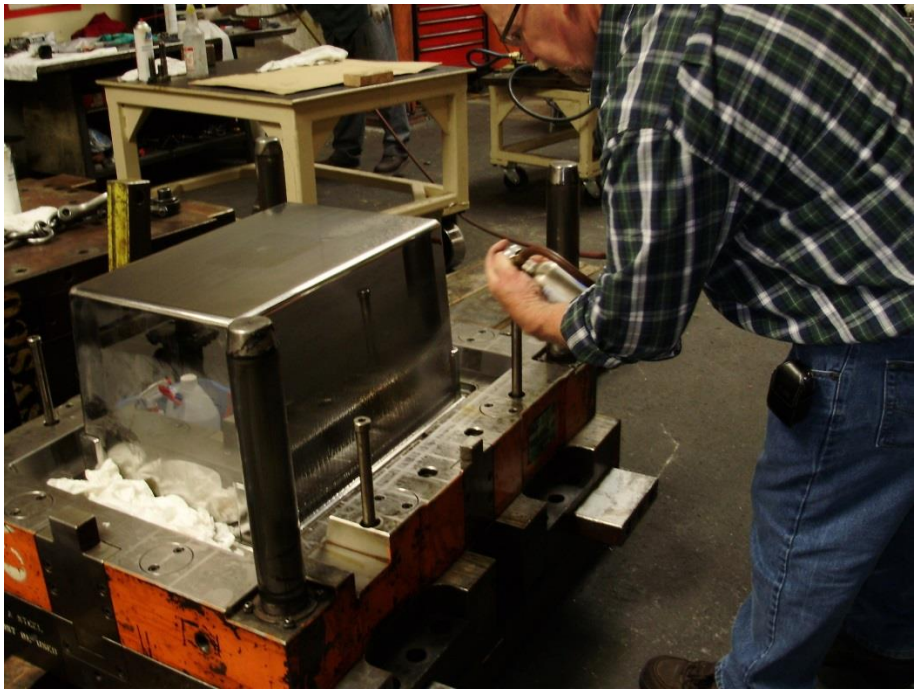

Figure 3-15 Metal Mold at CAMBRO

IRTA worked with CAMBRO to develop alternative low-VOC materials and methods for cleaning the molds. Because aerosol products are expensive and difficult to dispose of, CAMBRO wanted to explore non-aerosol alternatives. Hexane is fairly fast evaporating so IRTA needed to develop alternative cleaners that would evaporate relatively quickly. IRTA and CAMBRO agreed that the alternative formulations should meet a 25 gram per liter VOC limit. IRTA also investigated non-chemical alternatives. In particular, IRTA had tested a dry ice blasting system for cleaning transformers in the past and wanted to pursue that option for this cleaning application.

3.8.1 Alternative Mold Cleaning Tests

IRTA formulated and tested a range of different formulations based on chemicals that are exempt from VOC regulation with the employees who routinely conduct the cleaning. Two of these formulations seemed to work well. One formulation was a blend of acetone and a glycol ether. Acetone is exempt from VOC regulations whereas the glycol ether is classified as a VOC. MSDSs for acetone and DPM are shown in Appendix B. IRTA arranged for a company called PSC Environmental Services to blend five gallons of the formulation and provide it to CAMBRO for longer term testing. The formulation, which has a VOC content of 23.7 grams per liter by volume, worked effectively, according to the CAMBRO employees. It did evaporate slightly faster than the hexane aerosol product, however, and the employees who perform the cleaning indicated they would like an alternative that evaporated somewhat more slowly.

IRTA tested PCBTF which, like acetone, is exempt from VOC regulation. The employee who tested it thought it cleaned well but indicated he would like it to evaporate a little more quickly. IRTA blended the PCBTF with various concentrations of acetone to make it evaporate more quickly and the employee indicated that a 50%/50% blend of acetone and PCBTF by volume performed best. This blend, because it is composed of two exempt solvents, has a VOC content of zero. IRTA provided larger quantities of the blend to the company and it seemed to work well and have the preferred evaporation characteristics.

IRTA also tested another alternative for the cleaning, a dry ice blasting system. IRTA brought in a system supplier who indicated that CAMBRO already owned a dry ice system. IRTA and the supplier found the system which was being used for other applications and tested it for cleaning the mold protectant from the molds.

Pictures of the testing conducted with the cleaners are shown in Figures 3-16 and 3-17 Figure 3-18 shows the tests with the dry ice blasting system.

Figure 3-16 Spraying Baseline Hexane Aerosol on Mold

Figure 3-17 Testing Alternative Cleaner on Metal Mold

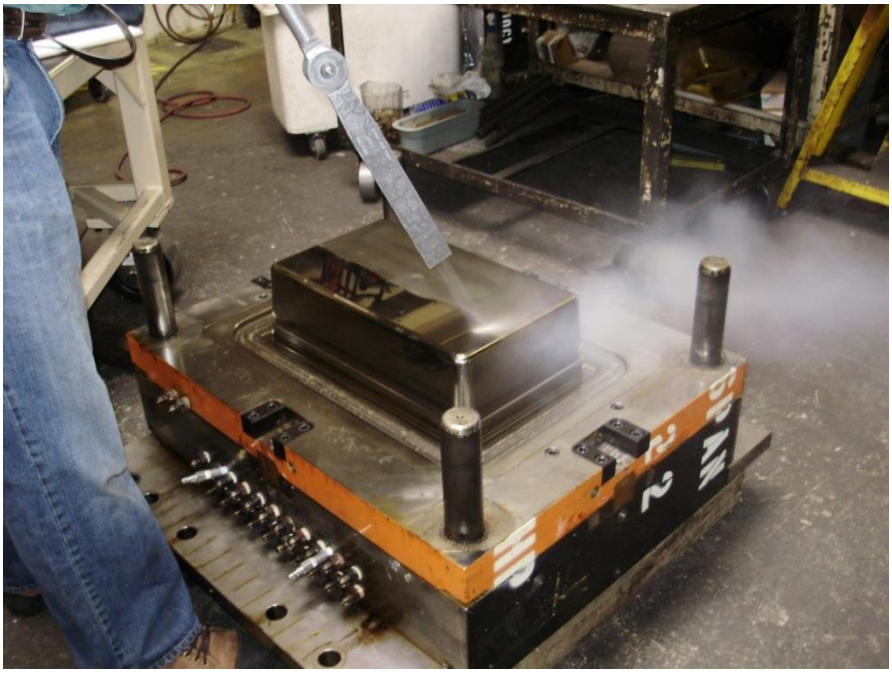

Figure 3-18 Testing Dry Ice Blasting System on Metal Mold

3.8.2 Cost of Using Baseline Aerosol Cleaner

IRTA conducted a cost analysis and comparison of the hexane that is used today and the two alternative low-VOC, low toxicity chemical products. CAMBRO currently purchases 9,800 13 ounce cans of the hexane aerosol cleaner or 7,962.5 pounds per year. The cost of the cleaner is $4.21 per can and the total cost of purchasing the hexane aerosol cleaner amounted to $41,258 in 2011.

In addition to the cleaner purchase cost, CAMBRO must dispose of the aerosol cans when they are empty. CAMBRO is charged $185 per drum for disposal of the empty cans. CAMBRO staff counted the number of cans in a drum and found that each drum contained between 146 and 162 cans, depending on the size of the cans and how they are packed. On this basis, assuming a drum contains 152 cans and that 9,800 cans require disposal, CAMBRO disposed of 64.5 drums. At a disposal cost of $185 per drum, the cost of disposal of the hexane cleaner amounted to $11,932.50 in 2011. Adding in markup and taxes, the total disposal cost in 2011 was about $14,916.

3.8.3 Cost of Using Acetone/Glycol Ether Alternative Cleaner

For the cost analysis of the first alternative, IRTA assumed that the weight of the alternative cleaner required for cleaning would be equal to the weight of the hexane aerosol used today. Thus, 7,962.5 pounds of the alternative cleaner would be needed. The first alternative cleaner, the blend of acetone and glycol ether, is primarily acetone and, using the acetone specific gravity of 0.79 at 20 degrees C or about 6.6 pounds per gallon 1,206 gallons per year of this alternative cleaner would be required.

IRTA obtained a cost estimate from PES for CAMBRO to purchase the alternative product in two different ways. PES indicated that CAMBRO could purchase five gallon containers of the cleaner at a cost of $95 per five gallon pail. PES also indicated that CAMBRO could purchase the cleaner in drum quantities at a cost of

$503 per drum if one drum were purchased at a time. The price is lower, at $479 per drum, if CAMBRO decided to purchase two to four drums at a time. If CAMBRO elected to purchase five to nine drums at a time, the price would be even lower, at $464 per drum. Each drum requires a $35 deposit but PES gives a refund of $15 per drum when the drum is returned empty.

Assuming CAMBRO wanted to purchase the cleaner in five gallon pail quantities, the company would need about 241.2 pails per year. On this basis, the annual cost of purchasing the alternative cleaner would be $22,914. If CAMBRO decided to purchase the cleaner in 55 gallon drum quantities, the company would need to buy 21.9 drums per year at a total annual cost of $11,016. In addition, there would be a net additional deposit cost of $438 based on CAMBRO getting a refund for the drum deposit. The total cost of purchasing the alternative cleaner in one drum quantities would be $11,454.

In the case of the alternative, there would be no disposal cost. This follows from the fact that the cleaner evaporates during the cleaning and no aerosol cans are used.

Table 3-7 shows the cost comparison for the current hexane cleaner and the alternative acetone/glycol ether cleaner. The figures show that, if CAMBRO purchased five gallon pails of the alternative cleaner each year, the cost would be lower than the current cost by 59 percent. If CAMBRO purchased the cleaner in one drum quantities, the cost would be lower by 80 percent.

Table 3-7
Annual Cost Comparison of Current and Alternative Acetone/Glycol Ether Cleaners for CAMBRO

	Hexane Aerosol Cleaner	Alternative Cleaner (Five Gallon Pails)	Alternative Cleaner (One Drum Quantities)
Cleaner Cost	$41,258	$22,914	$11,454
Disposal Cost	$14,916	NA	NA
Total Cost	$56,174	$22,914	$11,454

The costs in Table 3-7 could be higher for the alternative cleaner in practice. The cost analysis assumes that the amount of the alternative cleaner that is used will be the same as the amount of the hexane aerosol cleaner. Acetone has a very high volatility and evaporates quickly so it is possible that more of the alternative cleaner would be required. If 10 percent more of the alternative cleaner were required, the cost of purchasing the alternative cleaner would be higher. Even under this assumption, however, the cost of using the alternative cleaner would still be considerably lower than the cost of using the aerosol cleaner.

3.8.4 Cost of Using Acetone/PCBTF Alternative Cleaner

For the cost analysis of the second alternative, IRTA again assumed that the same weight of cleaner would be required. The blend is 50% acetone/50% PCBTF by volume. Assuming a liquid density of 6.6 pounds per gallon for acetone and 11.2 pounds per gallon for PCBTF, about 905 gallons of the blend would be required to substitute for the 7,962.5 pounds of hexane. On this basis, assuming a density of 8.8 pounds per gallon for the blend, CAMBRO would require about 895 gallons per year of the alternative.

A supplier called Specialty Products Company (SPC) is willing to provide the blend to CAMBRO. The charge would be $193.75 for a five gallon pail (about $39 per gallon) or $1,599 per drum (about $29 per gallon). SPC would require CAMBRO to purchase a minimum quantity of 44 five gallon pails or a minimum quantity

of four drums and they would have to be ordered in these increments. Since CAMBRO would have to purchase 895 gallons per year of the cleaner, the company could easily order in the increments specified.

Assuming CAMBRO decided to purchase the alternative cleaner in five gallon pails, the company would need 179 pails per year. At a cost of $193.75 per pail, the total cost of this option is $34,681 annually. If the company opted to purchase the alternative cleaner in drums, the company would require about 16.3 55 gallon drums and the annual cost would amount to $26,020. As expected, the cost of purchasing the alternative cleaner in larger quantity containers is lower.

In this case, as for the first alternative cleaner, there would be no disposal cost since the cleaner evaporates during the cleaning and aerosol cans are not used.

Table 3-8 shows the cost comparison for the current hexane cleaner and the alternative cleaner containing acetone and PCBTF. The figures show that, if CAMBRO purchased five gallon pails of the alternative cleaner each year, the cost would be lower than the current cost by 38 percent. If CAMBRO purchased the cleaner in one drum quantities, the cost would be lower by 54 percent.

Table 3-8
Annual Cost Comparison of Current and Alternative Acetone/PCBTF Cleaners for CAMBRO

	Hexane Aerosol Cleaner	Alternative Cleaner (Five Gallon Pails)	Alternative Cleaner (One Drum Quantities)
Cleaner Cost	$41,258	$34,681	$26,020
Disposal Cost	$14,916	NA	NA
Total Cost	$56,174	$34,681	$26,020

Again, the comparative analysis is based on the assumption that the same weight of the cleaner would be required for this alternative. If more cleaner were required in practice, the cost savings from the conversion would be less. It is worth noting that it is less likely that more cleaner would be required in this case. The first alternative has a much higher acetone content and acetone has a very high volatility and evaporates quickly. It is therefore more likely that a greater weight of cleaner would be required for the acetone/glycol ether alternative than for the acetone/PCBTF cleaner in which the acetone content is lower.

3.8.5 Cost of Using Dry Ice Blasting System

CAMBRO owns a dry ice blasting system which relies on carbon dioxide pellets to remove contaminants from various surfaces. The device is currently used by CAMBRO in other applications. IRTA and CAMBRO tested the existing system to determine whether it could effectively remove the mold protectant from molds. The testing confirmed that the mold protectant could be removed easily from the mold using the device.

To estimate the costs of using the dry ice blasting system instead of a chemical cleaner for removing the mold protectant, information on the number of molds cleaned and the square footage of those molds was needed. The mold shop manager estimates that about 20 molds are cleaned per day and that the average size of the mold is one foot by 1.5 feet. On this basis, 30 square feet of mold surface is cleaned per day. Assuming the mold cleaning is performed 260 days per year, 7,800 square feet of mold surface are cleaned per year.

Using the current process, the employee positions the mold, sprays the mold surface with the aerosol, wraps toilet tissue around his hand and wipes the toilet tissue over the mold. The actual cleaning process, including spraying and rubbing with the toilet tissue, may take no more than about one minute for each mold. Under this assumption, the labor hours for the cleaning amount to 20 minutes per day or about 87 hours per year. The estimate for the cleaning time does not include removing the molds from storage and positioning them since any method of cleaning would require those activities.

When the dry ice system was used to remove the mold protectant, the process was very quick and took no more than one minute. The dry ice blasting system supplier indicates that the system can clean contaminants like the mold protectant from the mold surface at a rate of seven to 10 feet per minute. Even if the cleaning rate was much lower, at 1.5 feet per minute, the labor used for cleaning the mold would be no more than one minute per mold. Assuming that the blasting system takes no more than one minute to clean a mold, the labor cost of cleaning the molds with this technology would be the same as the labor cost of cleaning with the aerosol cans.

Since the company already owns a dry ice blasting system, there would be no capital cost to CAMBRO for purchasing the device. IRTA wanted to analyze the case where a company did not already own a system, so both situations are considered here. The cost of a system like the one CAMBRO owns is $15,000 to $20,000. Assuming the midpoint, the capital cost of the system is $17,500. If the company does not have a compressor, they would have to purchase one capable of delivering 185 cfm. The cost of such a compressor is about $8,000. The total capital cost of the equipment would amount to $25,500. Using a conservative cost of capital of four percent, the annualized cost of purchasing the equipment, assuming a useful life of 10 years, would be $2,652.

The dry ice used for the blasting system must be purchased and is an operating cost. The system supplier estimates that 1.5 to two pounds of dry ice per minute would be used for this cleaning task. Taking the higher value to be conservative and assuming a cost for the dry ice of 34 cents per pound, the cost of purchasing the dry ice would amount to $13.60 per day or $3,536 per year.

The electricity cost of operating the system must also be considered as an operating cost. The dry ice blasting system is a 120 volt, 8.2 amp system. On this basis, it requires 0.984 kW. Based on the operating time of 20 minutes per day, the system would use 85 kWh per year. Assuming an electricity cost of 12 cents per kWh, the total electricity cost would amount to $10.

Table 3-9 shows the annualized cost comparison for the current cleaner and the dry ice blasting system. The values show that the dry ice blasting system with or without the need to purchase a new system is the lowest cost option.

3.8.6 Summary of CAMBRO Results

The analysis demonstrates that the cost of using either of the low-VOC solvent alternatives is lower than the cost of using the hexane aerosol cleaner. The cost of using the acetone/glycol ether blend is the lowest but the employees did not like the cleaner as well as they liked the acetone/PCBTF blend. Both cleaners meet the 25 gram per liter VOC content limit specified by IRTA and CAMBRO for the alternative.

Table 3-9 Annualized Cost Comparison for Current Cleaner and Dry Ice Blasting System for CAMBRO			
	Hexane Aerosol Cleaner	**Dry Ice Blasting (No System Purchase)**	**Dry Ice Blasting (System Purchase)**
Capital Cost	NA	NA	$2,652
Cleaner Cost	$41,258	NA	NA
Dry Ice Cost	NA	$3,536	$3,536
Electricity Cost	NA	$10	$10
Disposal Cost	$14,916	NA	NA
Total Cost	$56,174	$3,546	$6,198

The lowest cost method of removing the mold protectant is to use the dry ice blasting system, particularly since CAMBRO already owns such a system. This option is substantially lower in cost than using a chemical formulation for the cleaning. The analysis was performed assuming that the labor cost of using the blasting system is the same as the labor cost of using the hexane or alternative solvent cleaner. It is likely that less labor would be required in the case of the blasting system, but even if the labor required was twice as much with the blasting system, the cost of using the dry ice system would still be lower than the cost of using a solvent. The labor cost for the mold shop employees is estimated by CAMBRO to be $41 per hour including benefits. If the cleaning labor were 174 hours per year instead of 87, the labor cost for using the blasting system would be higher by $3,567. Adding this to the total cost would result in a blasting cost of $7,113 per year. This is still lower than the annual cost of using any of the chemical cleaning alternatives.

Table 3-10 presents a summary of all of the options.

Table 3-10 Annualized Cost Comparison of All Cleaning Options for CAMBRO	
Option	**Annualized Cost**
Hexane Aerosol Cleaning	$56,174
Acetone/Glycol Ether Cleaning (five gallon pails)	$22,914
Acetone/Glycol Ether Cleaning (drums)	$11,454
Acetone/PCBTF Cleaning (five gallon pails)	$34,681
Acetone/PCBTF Cleaning (drums)	$26,020
Dry Ice Blasting (no system purchase, same labor)	$3,546
Dry Ice Blasting (no system purchase, double labor hours)	$7,113
Dry Ice Blasting (system purchase, same labor)	$6,198
Dry Ice Blasting (system purchase, double labor hours)	$10,680

IV. Inventory of VOC Emissions and Issues for Alternatives

This section provides estimates of the inventory of VOC emissions for the sectors of interest in this project. IRTA worked with a variety of industry sources to make the estimates. The SCAQMD uses the inventory figures in the rulemaking process. The section also identifies two issues that may arise if the alternatives identified and tested during this project are used in field applications. Finally, some areas where future work may be necessary are identified.

4.1 VOC Emissions Estimates

For each of the three applications where release agents were identified, developed, tested and demonstrated, IRTA made estimates of the current level of VOC emissions. Different approaches were used for each of the categories and subcategories where VOC materials are currently used. The approach used in each case is described in detail below. In all cases, the focus was on VOC emissions in the SCAQMD jurisdiction which includes Los Angeles, Orange, Riverside and San Bernardino Counties, a large area that represents about half the state in terms of emissions.

4.1.1 VOC Emissions From Concrete Stamping Operations

IRTA worked with two companies that sell mineral spirits release agents currently into the concrete and concrete overlay stamping markets. In 2011, Proline, located in Oceanside, California, indicates the company sold 1,062 gallons of release agent and estimated that their contribution to the market amounts to 1%. On this basis, the total market for the release agents in the South Coast Basin in 2011 was 106,200 gallons per year. Proline also indicates that there has been growth of between 15 and 20% since then. Assuming a growth of 17.5%, the market is now 124,786 gallons per year according to this estimate.

Another supplier from outside the state, Solomon Colors, indicated that the California market for liquid release agents in 2011 might have been as high as $1 million. Assuming an average price of $16 per gallon for the release agent, about 62,500 gallons were sold. The company also estimates that growth in the market since then has been about 10% which translates into a market size of 68,750 gallons per year. The South Coast Basin accounts for roughly half of California so release agent sales in SCAQMD would amount to 34,375 gallons per year according to this estimate..

IRTA asked several different sources for estimates of release agent use in the concrete and concrete overlay stamping as a portion of the total market for release agents. Multicoat indicated overlay stamping might account for as much as one-fourth to one-third of the total market. Proline indicated it is more toward the lower figure. Solomon Colors suggested it is even lower, at between 15 and 20%. For purposes of analysis, IRTA assumed the stamped overlay release agent market is 25% of the total market. Based on the range of 34,375 to 124,786 gallons for the total market, the concrete stamping market is 25,781 to 93,590 gallons per year and the concrete overlay market is 8,594 to 31,196 gallons per year. These estimates were used in the industrywide cost analysis for the alternative release agents in Section II.

Using the overall market estimates from Proline and Solomon Colors, IRTA developed a low and high estimate of the inventory of VOC emissions from concrete stamping operations. The Solomon Colors low estimate is 34,375 gallons per year and the Proline high estimate is 124,786 gallons per year. Assuming a liquid density for mineral spirits of 6.84 pounds per gallon, the range is 0.32 to 1.17 tons per day.

4.1.2 VOC Emissions from Asphalt Operations

IRTA identified asphalt applications as an area where release agents are used near the end of the project and it was not in the original project workplan. As a result, it was more difficult to develop a complete estimate of the emissions from this category.

There are three sectors in the asphalt industry where release agents are used. These include asphalt production plants, asphalt road and highway applications conducted by cities and counties and asphalt operations conducted by private contractors. Emissions from each of these sectors are discussed below. There are several plants that manufacture asphalt roofing tiles located in the South Coast Basin. These companies may use release agents in their processes, but IRTA did not have time or resources to investigate this use during the project so this sector is not considered here.

IRTA worked with one asphalt production facility that provided estimates for the emissions from asphalt production plants in the South Coast Basin. This company, which is not located in the SCAQMD jurisdiction, routinely uses diesel fuel to prevent asphalt buildup on drums, conveyors and trucks used in the asphalt production process. This company uses 15 gallons per day of diesel fuel as a release agent. Although there are larger and smaller plants, the plant manager indicates that this is probably a reliable average usage for the plants in the South Coast Basin. He estimates that there are 20 asphalt production facilities each in Los Angeles, San Bernardino and Riverside counties and eight facilities in Orange County. Assuming that each of these 68 facilities uses 15 gallons per day, total asphalt production facility VOC emissions amount to 1,020 gallons per day.

IRTA worked with the City of Simi Valley and, although the city is not located in the South Coast Basin, it is likely to be representative of other cities in the Basin. The City uses diesel fuel to prevent asphalt buildup on equipment used to apply asphalt to the roads. Simi Valley indicates their usage amounts to 100 to 200 gallons per year and IRTA used a value of 150 gallons per year for the analysis in Section II.

For estimating total emissions from this sector, IRTA assumed that the asphalt operations in cities would be proportional to population. The population of Simi Valley is 125,793. The population of California is 38,041,430; assuming the South Coast Basin includes half the population of California, the population in the District jurisdiction is 19,020,715. On this basis, VOC emissions of release agents from cities in the District jurisdiction performing asphalt operations amount to about 62 gallons per day.

Other asphalt operations are conducted by Cal Trans for the freeway systems and by private companies for resurfacing parking lots, driveways and public and private roads. Cal Trans operations are almost always performed by outside private contractors. IRTA contacted the Asphalt Pavement Association (APA) and the trade association apparently has many members who are private contractors. An APA representative indicated that the private contractor work processes between five and 25 times as much asphalt as cities. Assuming the midpoint of 15 times and that the asphalt processing volume is proportional to diesel fuel use as a release agent, private contractor emissions amount to 930 gallons per day.

The total amount of diesel emissions from asphalt plants, city and private contractor operations is 2,012 gallons per day. Using an average liquid density for diesel fuel of 7.1 pounds per gallon, the total inventory of emissions for the asphalt sector amounts to 7.14 tons per day.

4.1.3 Emissions from Molding Operations in Parts Manufacturing

IRTA worked with a number of different types of manufacturing plants that mold parts made of a range of different substrates as part of the process during this project. IRTA also worked with several suppliers during the project but most of them focused on certain specific types of parts molding and they were unable to provide useful information on emissions for the industry as a whole.

With these limitations in mind, for this category, IRTA considered three sources of data. IRTA obtained the most comprehensive estimate from Henkel, a company that sells mold release agents, mold sealers and mold cleaners all over the world. The company collects market research data and IRTA relied on this information for one of the estimates. IRTA contacted several other suppliers but only one was able to provide an estimate of a small segment of the market. This latter estimate was developed in a bottom up manner. The District made an estimate of the VOC emissions from composite facilities in a preliminary draft staff report for "Proposed Amended Rule 1162—Polyester Resin Operations." The emissions estimates from these three sources are discussed below.

4.1.3.1 Henkel Marketing Research

Henkel divides the data into three sectors. The first sector is the liquid mold release related sector and U.S. sales in that sector amount to $100,000,000 per year. The second sector is Teflon coated molds or silicon related materials for plastic injection molding and wax based mold operations. U.S. sales in this sector amount to $60,000,000 per year. Teflon coated molds do not need mold release agents; subtracting out these molds at 10%, as estimated by a Henkel representative, leads to an estimate for this sector of $54,000,000 per year. The third sector represents sales for tires and low density urethane applications and it is estimated at $82,000,000 per year. The sum of all three sectors is $236,000,000 per year.

The price of a typical product, according to the Henkel representative, is about $100 per gallon. Under this assumption, the amount of materials used in the U.S. is 2,360,000 gallons per year. California accounts for about 10% of the total and the South Coast Basin accounts for 6% of the total. On this basis, there are 141,600 gallons of mold release agent sold in the Basin per year. About 70 percent of the market is solvent and the rest is water-based, which leads to an estimate of solvent release agent sales of 99,120 gallons per year. Assuming a solvent content of 97%, the value is 96,146 gallons per year. Using a density of 7 pounds per gallon and dividing by 2,000 leads to a figure of 336.5 tons per year. Dividing by 365 days per year, the VOC emissions inventory estimate is 0.92 tons per day.

Henkel's marketing research was performed a few years ago and is likely to be representative of the 2011 status of the market. A Henkel representative provided IRTA with an update recently. He indicated that there had been a decline in the sales of mold release agents for fiberglass applications in the last few years but there had also been an increase in the sales of mold release agents for composite applications. The representative believes that the decline and increase roughly offset each other so that the inventory estimate for today remains the same as the earlier estimate.

4.1.3.2 Western Marine Marketing Estimates

This company has a manufacturing representative who carries various products. He provided a bottom up estimate for one segment of the molding industry, primarily the fiberglass users who still rely on wax based products. This would be a subset of the second sector of the Henkel market research data described above. The manufacturing representative estimates that the wax mold release sector amounts to $120,000 in sales

per year excluding mold cleaners. He includes sealers in the estimate which also contain solvents and he estimates sealers would account for 15 to 20% of the amount. The price of one can of wax mold release agent is about $10 for 11 ounces of material. This translates into 8,250 pounds or 4.13 tons per year of materials. A typical paste wax mold release may contain 70 percent solvent so the VOC emissions amount to 0.01 tons per day. It would be expected that this estimate would be much lower than the Henkel estimate since wax based mold release agents account for only a small portion of the market.

4.1.3.3 SCAQMD Polyester Resin Estimate

The draft staff report estimates that VOC and HAP emissions from composite facilities amounts to 553.93 tons per year based on the District's 2008 Emissions Inventory. The document estimates that the average emissions from solvents, coatings and adhesives from composite operations are 10.75% of total emissions. This leads to VOC emissions from the composite category of 0.16 tons per day. The composite sector is only a portion of the market so this estimate is not inconsistent with the other estimates from Henkel and Western Marine Marketing.

4.4.4 VOC Emissions from Form Release Applications

SCAQMD Rule 1113 "Architectural Coatings" currently regulates form release agents that are used for poured concrete by contractors. When the concrete is poured, wood slats are generally used on the outer perimeters of the area to contain the concrete. A release agent is applied between the wood and the concrete. The VOC limit in Rule 1113 for such release agents is 250 grams per liter. This limit is scheduled to decline to 100 grams per liter on January 1, 2014.

As discussed earlier, IRTA worked with Oldcastle Precast, a company that makes concrete molded parts as part of this project. The supplier indicated that the release agent currently used by the company meets the Rule 1113 VOC limit for form release agents, which means that it contains less than 250 grams per liter VOC. Oldcastle's operations are not subject to the Rule 1113 VOC limits since the rule regulates architectural coating operations, not parts manufacturing. The emissions from manufacturing concrete parts in all plants in the Basin would be included in the Henkel estimates derived earlier.

The alternatives IRTA tested with Oldcastle Precast and with Proline and Multicoat for concrete stamping should be suitable for use in architectural form release operations. These alternatives had a VOC content of 25 grams per liter or less. On this basis, the District could modify Rule 1113 to specify a limit of 25 grams per liter VOC for the form release category. The inventory for this category is estimated by the District to be about 0.08 tons per day.

4.4.5 VOC Emissions from Mold Cleaning

SCAQMD Rule 1171 "Solvent Cleaning" regulates cleaning agents used for repair and maintenance cleaning and the VOC limit for these cleaners is 25 grams per liter. The cleaners used in the molded parts manufacturing sector are covered by this category. Even so, IRTA found that the industry is not aware that their cleaning is subject activities are subject to Rule 1171. When the District develops source specific rules, the rule language generally contains a reference to Rule 1171 so the companies subject to the source specific rule will know they must meet the Rule 1171 limit for cleaning materials. Since there is no source specific rule for molded parts manufacture, it is not surprising that the industry does not think cleaning materials are regulated. The District could add a category of cleaning to Rule 1171 called mold cleaning to

clarify the requirements for the industry. There is no VOC emissions inventory for this category since it has already been taken into account in Rule 1171.

4.2 Issues of Concern with Adoption of Alternatives

There are two major issues that arise if the alternatives were to be adopted in the sectors of focus in this project. The first issue concerns the use of release agents in concrete stamping and the second concerns the status of PCBTF. Each of these issues is discussed in more detail below.

4.2.1 Concrete Stamping Release Agents

Contractors have historically used powder release agents between the bottom of the mats containing the pattern and the concrete as it is curing during concrete and concrete overlay stamping jobs. Over the last several years, liquid release agents have emerged and contractors, particularly in concrete overlay stamping, are using the liquid release agents in place of the powder. The liquid release agents are generally mineral spirits formulations.

During the stamping process, contractors often also apply color packets to the concrete. These color packets are generally in powdered form. After the concrete is cured, a residue from the powder or liquid release agent and the color powder packets may remain. Suppliers of the release agents instruct contractors to rinse the concrete the next day to remove the residue. This is particularly necessary if the contractor plans to apply a stain to the concrete; the concrete will not accept the stain if there is still a residue on the surface. Even in cases where color packets are used, a stain may be applied later to the colored concrete to obtain the desired effect.

The Regional Water Quality Control Districts (RWQCBs) regulate the wastewater that is discharged to the storm drain. Generally, only rain water is allowed into the storm drain and the Regional Boards do not allow water or other material from any other source to be discharged. The effect of this requirement is that contractors at job sites must collect the water they use to rinse the concrete. When contractors rinse the concrete, they generally use a hose and flush all of the material from the surface of the concrete. In Northern California, particularly in the city of San Francisco, the wastewater may go through a Publicly Owned Treatment Works (POTW) so the water from the rinsing operation is treated. In these cases, the contractors may be able to release the effluent from the rinsing operation without collecting it. In most of California, however, almost none of the water goes through a POTW treatment facility so the rinsewater must be collected.

Another agency with jurisdiction over the rinsing operation is Cal/EPA's Department of Toxic Substances Control (DTSC). At the local level, the California Unified Program Agencies (CUPAs) enforce the hazardous waste regulations. In the case of concrete stamping, if the rinsewater ends up on the ground, the contractor must conduct tests to determine if it is hazardous waste. In this event, the contractor should take a sample of the rinsewater and conduct an aquatic toxicity test. One of the measures of whether or not a material is classified as hazardous waste is whether or not it exhibits aquatic toxicity. The material is diluted and put in a container with fathead minnows and, depending on the test results, the rinsewater may or may not be classified as hazardous waste. The aquatic toxicity test would not be necessary if the water is properly collected.

There are various methods of collecting the rinsewater from the concrete rinsing operation. Concrete forming operations are often conducted at job sites where concrete stamping is done. The forms outline the

footprint and hold the concrete in place. The forms can be extended upward and when the concrete is rinsed the next day, they will hold the rinsewater which can be vacuumed up with a wetvac. In effect, the form can be used to berm the water so it is not released to the storm drain. Another approach is to use absorbent to collect the liquid in the areas defined by the forms.

Conversion to the low-VOC alternative liquid release agents will not change this situation assuming contractors are complying with the regulations and collecting the rinsewater. The same requirements apply to the alternatives as apply to the powder and liquid release agents used today. One difference is that the low-VOC alternative liquid release agents tested during this project have lower volatility than the liquid release agent used today. There may be a higher concentration of them in the rinseate as a result. Another option considered here is for contractors to use powder release agents rather than the high VOC liquid release agents used today. Since powder release agents are already used for about 80% of the stamping operations, this would have little impact, again assuming contractors are complying with the regulations.

4.2.2 PCBTF Toxicity Status

One of the alternatives tested and evaluated during this project is PCBTF. It was used as an ingredient in a mold release agent formulated for and tested during this project. It was also tested as a cleaning agent for molds used to make fiberglass parts where the companies are using wax mold release agents and for removing mold protectant from metal molds. Finally, it was tested as a release agent for concrete and concrete overlay stamping.

PCBTF has been exempt from VOC regulations for several years and it is used widely to comply with VOC limits in the South Coast Basin. When the chemical was first marketed, IRTA was concerned about the chemical because structurally, it contains a benzene ring with a chlorine substituent. Other chemicals with similar structure have been shown to be toxic in various ways. In the past, the chemical had not been tested for carcinogenicity, so no conclusion could be made regarding that endpoint.

During this project, IRTA became aware that the National Toxicology Program (NTP) is currently completing an animal carcinogenicity test for PCBTF. Appendix C includes a description of the status of the results. It indicates that the NTP has completed the two year inhalation study in rats and mice and is currently conducting the histopathology. The results are expected to be available in 2015. If the results indicate that PCBTF is a carcinogen, government agencies could act to restrict the chemical and it would not be good public policy to promote its use even though it is not classified as a VOC.

With this in mind, the possible future uses of the chemical as a release agent and/or cleaning agent must be evaluated. As indicated above, IRTA tested the chemical as an ingredient in a release agent. The PCBTF release agent was tested at the anonymous boat manufacturing facility for making parts and it worked effectively. A water-based release agent was tested in the same application and it also worked effectively. This demonstrates that there is no need to use the PCBTF release agent in applications where fiberglass parts are made.

IRTA also tested the PCBTF and the water-based release agents at Foam Molders. Only the PCBTF release agent worked effectively to make two parts in the operation selected for testing. Foam Molders does use some water-based mold release agents today and might be able to expand their use of these agents to some of their other parts. For the parts that cannot use the water-based release agent, suppliers would have to develop other release agents that did not contain PCBTF but met the lower VOC limits SCAQMD may establish. If this were not possible, SCAQMD could provide exemptions for certain parts to allow the release

agent to have a higher VOC content. During the project, IRTA formulated an alternative release agent with the limitation that it could contain no more than 25 grams per liter VOC. IRTA could have developed a release agent with a carrier that is a blend of acetone and DPM, a glycol ether, that could likely meet a VOC content limit of 100 grams per liter.

In cleaning applications, IRTA tested various low-VOC alternatives for cleaning the non-skid areas of the molds where wax based mold release agents are used at the boat manufacturing facility. PCBTF was the only effective alternative. However, the company has another option which is to convert to a liquid release agent. Companies using liquid release agents do not have to clean their molds with anything except a small amount of acetone now and then. Since the liquid water-based release agent worked well to make several parts at this facility, the company could convert to this alternative. The cost of using the liquid release agent would be lower than the cost of using the wax based mold release agent since less labor is used in this case and more parts can be made without reapplication. Thus, PCBTF does not have to be used to clean molds where wax mold release agents are used.

PCBTF was also tested in a blend with acetone for cleaning the metal molds at Cambro. Other alternatives, including the blend of acetone and DPM, a glycol ether, and the dry ice blasting system were also effective. Both of these other options were also less costly than using the PCBTF/acetone blend. Thus, there is no need for Cambro to use PCBTF in the cleaning process.

PCBTF was tested during the project as an alternative release agent for concrete stamping. It cannot be used when color packets are used during the release process because it bleaches the color from the concrete. It could be used in about 15% of the concrete stamping operations and 70% of the concrete overlay stamping operations where color packets are not used during the stamping process. The cost analysis demonstrated, however, that PCBTF would be a very poor choice as a release agent in these applications since other release agents were much less costly to use. All of the other release agents tested were less costly to use than the PCBTF and it is unlikely that anyone would use it for these applications in any case.

If the NTP toxicity tests indicate that PCBTF is a carcinogen, it would not be prudent to use it in release agent and cleaning applications. During this project, IRTA found that there are other options that companies can use to meet new, more stringent VOC regulations if SCAQMD decides to propose them. In one case, Form Molders, SCAQMD might have to allow a higher VOC limit for certain selected parts operations but these would lead to minimal VOC emissions.

4.3 Future Work

IRTA has identified two areas where further work could be useful for finding effective alternatives in the sectors included in this project. The first area is non-stick coatings. The Neverwet non-stick coating made by Rust-Oleum was tested in a limited way. Durability testing on this coating under field conditions should be conducted to see if it could survive the stamping process. Other non-stick coatings should also be investigated further since one of them could prove feasible and cost effective. Such coatings are of great value since they could make use of release agent, whether it be powder or liquid, unnecessary.

The second area is asphalt roof tile manufacturing. This industry should be investigated further to determine if a high VOC release agent is used in the production plants. The recycled vegetable oil is likely to prove effective and its use could result in a significant VOC reduction.

V. Results and Conclusions

During the project, IRTA identified, developed, tested and demonstrated alternative release agents for concrete and concrete overlay stamping, asphalt production and use and molding during parts manufacturing. IRTA also focused on finding alternatives for cleaning fiberglass molds where wax based mold release agents are used and for removing mold protectant from metal molds. This section reviews and summarizes the project findings for each of the sectors.

5.1 Release Agents for Concrete and Concrete Overlay Stamping

Contractors currently use high VOC content mineral spirits as a release agent for concrete and overlay stamping. IRTA tested four low-VOC content alternatives that performed well for part or all of the stamping operations. The findings indicate that three of the alternatives, WD 40, PCBTF and recycled vegetable oil, can be used for stamping operations where integral color is not applied during the stamping process. Another alternative, a Dodge Oil petroleum based lubricant, can be used in place of the mineral spirits for all types of stamping operations.

IRTA evaluated and compared the cost of using the mineral spirits and the alternatives. The results indicate that the Dodge Oil product is somewhat more costly to use than the mineral spirits, assuming the same amount of material would be required. Since the product has lower volatility than the mineral spirits, less of it might be used and this would reduce the cost of using it. The recycled vegetable oil is less costly to use than the mineral spirits; this indicates that it could be the product of choice for concrete that is not colored during the stamping process. The WD 40 and the PCBTF are much more costly to use than the mineral spirits and it is not likely they would be considered viable alternatives by the industry.

5.2 Release Agents for Asphalt Manufacturing and Use

Asphalt manufacturing plants, cities and private contractors currently use diesel fuel as a release agent in their operations to prevent the asphalt from building up and sticking to surfaces. IRTA tested four low-VOC alternative release agents that performed acceptably. Two of the alternatives, Bango 250 and Holly 70, are petroleum based lubricants. The third alternative, WD 40, is a soy based lubricant. The fourth alternative, recycled vegetable oil, is a mixture of canola and soy vegetable oils recycled from restaurants. Although the first three alternatives performed adequately, the recycled vegetable oil was the preferred alternative. One of the companies that tested it indicated it worked more effectively than diesel.

The cost analysis and comparison indicated that all four of the alternatives are more costly to use than the diesel fuel assuming the same amount of the alternatives would be required. Because the alternatives have lower volatility than diesel fuel, however, in cases where asphalt is applied to roads, less of the release agents might be necessary. The lowest cost alternative, the recycled vegetable oil, is the most viable alternative for the industry.

5.3 Release Agents for Parts Manufacturing

IRTA worked with a variety of companies who manufacture and mold parts made of a range of different substrates including fiberglass, composite, foam and concrete. The industry currently relies on mold releases that use high VOC mineral spirits as a carrier solvent. IRTA worked with a supplier to formulate an alternative low-VOC mold release agent based on PCBTF which was tested in some of the applications. IRTA also tested a water-based alternative release agent that performed well in most applications.

Some companies who make fiberglass parts use wax based mold release agents because they are forgiving. The limitation of these release agents is that generally only one part can be made before reapplication is necessary. The results of the project indicate that the two alternatives IRTA tested work well in these applications and the advantage in using them is that multiple parts can be made before reapplication is necessary. The water-based release agent is less costly to use than the mold release agents used currently.

The water-based release agent also proved effective for a plant that molds composite parts used in the aerospace industry. This alternative is less costly to use than the solvent based aerosols that are used currently.

The PCBTF release agent seemed to perform adequately for making foam parts but the costs could not be evaluated because the company did not provide information required for the analysis.

IRTA tested three low-VOC alternatives that worked well with a concrete parts manufacturer. The alternatives included the PCBTF mold release agent formulated for this project, a Dodge Oil product and WD 40. This same company, at another location, is reportedly using recycled vegetable oil so that is a viable alternative as well. The cost of using the recycled vegetable oil is lower than the cost of using the current product. The cost of using the Dodge Oil product is only slightly higher than the cost of using the current material. The cost of using the WD 40 and PCBTF release agent are far higher than the cost of using the current material. The Dodge Oil product and recycled vegetable oil are the best options for this application. They are less volatile than the release agent used today so less of them could be required and the cost of using them would be even lower.

5.4 Mold Cleaning

IRTA worked with two types of operations during the project where molds are cleaned. The first is fiberglass molding operations where wax based mold release agents are used. Companies routinely use styrene for cleaning the molds. IRTA tested a variety of alternative cleaners and PCBTF proved to be the only one that is effective; using PCBTF in place of styrene would increase the cost of cleaning. IRTA also tested an alternative water-based release agent for making the fiberglass parts and it performed well and is less costly to use than the wax mold release. Companies using liquid release agents do not need to clean their molds so conversion to this water-based release agent would make cleaning unnecessary.

The second operation where cleaning is performed involves removing mold protectant from metal molds used in compression molding machines. The company is currently using hexane aerosol cleaners for this purpose. IRTA formulated two alternative blends that performed well and were lower in cost to use than the hexane aerosols. The best option, however, is for the company to use a dry ice blasting system for cleaning the molds; this option is the least costly method.

5.5 Summary of Alternative Low-VOC Options

Table 5-1 presents the alternatives that performed well during the testing with facilities or organizations involved in the different types of operations. IRTA has made a judgment of which options are the best from an overall standpoint when performance, cost, health and the environment are taken into account.

Table 5-1 Best Alternative Low-VOC Release Agents and Cleaners		
Type of Operation/Activity	**Alternative Option**	**Conditions**
Concrete Stamping	Dodge Oil Product	All Concrete
	Recycled Vegetable Oil	Uncolored Concrete
	Powder Release Agent	All Concrete
Asphalt Manufacture And Application	Recycled Vegetable Oil	
Fiberglass Parts Manufacture	Water-Based Release Agent	
Composite Parts Manufacture	Water-Based Release Agent	
Foam Parts Manufacture	PCBTF Release Agent	
Concrete Parts Manufacture	Dodge Oil Product Recycled Vegetable Oil	
Fiberglass Mold Cleaning	Water-Based Liquid Release Agent	No Cleaning Needed
Metal Mold Cleaning	Dry Ice Blasting	

5.5 VOC Emissions Inventory

IRTA estimated the VOC emissions from the sectors of focus in this project. These inventories represent the total emissions that could be reduced through adoption of all or some of the alternative options that proved promising from a performance and cost standpoint during the testing. Table 5-2 summarizes the estimates of the VOC inventory for each of the sectors. The values demonstrate that the largest contributor to the total inventory of emissions is asphalt manufacturing and use.

Table 5-2 Release Agent Inventory Estimates	
Sector	**Inventory (Tons Per Day)**
Concrete and Concrete Overlay Stamping	0.32 to 1.17
Asphalt Manufacturing and Use	7.14
Parts Manufacturing	0.92
Form Release	0.08
Total	8.46 to 9.31

5.6 Issues for Alternatives Adoption

IRTA identified two issues that may arise that could affect the adoption of the alternatives. The first issue involves the practice of rinsing the concrete after the concrete has been stamped. Most Regional Boards prohibit the release of anything other than rain water to the storm drain and they require that Best Management Practices be used to prevent the release. Contractors either use powder or liquid mineral spirits release agents today when they stamp concrete. The alternatives IRTA analyzed involve converting to a powder release agent or converting to low-VOC liquid release agents. If the alternatives are adopted, it is unlikely to change the situation. Contractors are required to collect the water they use today or the water they would use after conversion before it is released to the stormwater drain. This could be done by

berming the liquid and collecting it in a wetvac. If the rinsewater enters the soil, the contractor should conduct an aquatic toxicity test to demonstrate it is not classified as hazardous waste.
The other issue of concern is that PCBTF is currently undergoing chronic toxicity testing to determine if it is a carcinogen. IRTA tested PCBTF during the project as a release agent and as a component of a cleaner. In all cases but one, there were other less costly options that could be adopted. In the case of foam molding, the PCBTF release agent was the only alternative that proved effective. A higher VOC limit for this and similar applications could be specified if PCBTF proves to be a carcinogen.

5.7 Future Work

During the project, IRTA identified two topics that require future work. The first is finding a non-stick coating or mat that could be used in concrete stamping. This would make use of a release agent of any kind unnecessary. The second is to determine whether or not release agents are used in asphalt roofing tile manufacture. If so, the recycled vegetable oil could be tested to determine if it is a feasible alternative.