Toward a Systematic Approach to Evaluation and Resolution of Purging Issues in Thermoplastics Processing[1]

Frank Van Haste, General Manager, NOVACHEM

ABSTRACT

Purging issues (which encompass changes in color and/or resin type and the removal of contamination from equipment) historically have received little attention from engineering and production managements. The pressures to optimize productivity that prevail in the modern industrial environment make this kind of inattention unacceptable. The present paper describes a systematic approach to the evaluation and resolution of these issues that is commensurate with the importance of their impact on productivity and gives examples of the benefits that are derived when such an approach is adopted.

It has long been a fact of life in the thermoplastics processing industry that color changes, material changes and the presence of contamination in process equipment – collectively, purging issues – would negatively affect productivity. This has been accepted in the industry for two reasons: (1) because every facility faced the same problems, there was no differential effect on competitiveness; and (2) in the hierarchy of problems to be solved ranked by expected benefit, these issues were not at or near the top of the list.

It is, however, clear to all informed observers that the imperatives of management in today's manufacturing process environment have changed greatly. With the application of sophisticated command and control methodologies and the advent of global competition, any moderate-effort/high-benefit problems have been addressed effectively. In the set of issues yet to be addressed, purging issues now assume real significance. Furthermore, as some leading practitioners begin to deal with purging issues in an effective way they will gain a competitive advantage. The net result will be increasing consciousness of the need to bring the negative impact of purging issues to an irreducible minimum.

Heretofore a variety of *ad hoc* approaches have been employed to address purging issues on an episodic basis. Normally, emergent production problems have been addressed through such expedients as:

- Running large amounts of resin, preferably of a low melt-flow character;
- Partial or complete disassembly and mechanical cleaning;
- Symptomatic application of one or more formulated purging products.

The shortcomings of this episodic approach to purging issues include that it neglects underlying causes and fails to address whether the result actually represents a significant improvement.

An informed and systematic technical approach – the antithesis of the heretofore-typical episodic approach – is required to truly minimize the negative productivity impact of purging issues. The approach must be planned and implemented in an orderly way, consistent with good manufacturing engineering practices. Each of five steps must be implemented competently and sequentially:

1. **Describe** the current situation – Characterize current problems, current responses and the parameters of the op-

erational environment in quantitative terms.

2. **Analyze** the problem set – Postulate an exhaustive list of potential causal factors. Inspect equipment, evaluate processes and test materials as required to support an informed analysis.

3. **Develop** a solution set – The solution set may include equipment modifications, process changes, introduction of new tools and the re-specification of materials. Include explicit statements of realistic expectations.

4. **Implement** the solution set – Apply the proposed solutions, preferably on a "pilot program" basis, while being prepared to modify as required in reaction to emerging information.

5. **Assess** the results – Characterize the results quantitatively and compare with the starting situation and with expectations. Monitor the stability of results over time. Return to earlier steps if and when necessary.

Each of these steps will be discussed in detail, below.

Describing the Current Situation

It is completely insufficient to characterize a purging issue with a statement that an undesirable symptom exists (e.g., "There are black specks in the product", or "The black to white color change takes four hours"). Such a characterization will not support a meaningful analysis or the development of a rational solution.

A deep understanding of the problem requires a deeply detailed description of the situation in which it arises. This begins with the operational environment. The information to be catalogued must include:

- The design parameters of the affected system including equipment type and configuration, size of major components, presence (or absence) of key peripherals, any unusual characteristics or known problem areas.
- The operating parameters of the system including operating schedule, temperature profiles and material residence times.
- The maintenance history of the system including frequency of, and time since teardown and the physical condition of major components.
- The properties of all production materials involved in the issue including resin types, resin properties (melt flow indices, processing temperature ranges, critical temperatures, colors, additives, fillers) and regrind percentage.
- The type of purging issue to be addressed – color change, material change, or the presence of contamination – and the frequency and timing of its occurrence.
- The productivity impact of the purging issue, stated in dollar amounts if at all possible. Include cost of machine time lost, cost of excess labor, lost material value (cost less salvage value), cost of materials used in reacting to the problem, and profit forgone due to salable product not made.
- The normal response to the problem including steps taken when the issue is recognized, time elapsed from last good production to restoration of good production, products employed in addressing the issue, side-effects resulting from addressing the issue and effectiveness of the response.
- Any other information regarded as potentially relevant by any involved managers, technical support or supervisory personnel, or equipment operators.

The information described above can be compiled conveniently using a data collection sheet[2].

[2] A sample of such a Data Sheet can be found in the Appendix to this paper (or downloaded at http://www.novachem.net)

Analysis of the Problem Set

Assuming that the information gathered in the preceding step is complete, the extraction of potential causal factors will be straightforward in most cases. These factors will be classifiable as equipment-related, material-related and process-related.

In some cases a single factor will be critical in addressing the purging issue at hand while in other cases two or more factors may interact to generate the problem. Also, some factors may prove readily remediable while others will be very difficult to address without a major transformation in the process environment.

Several initial questions can be asked that will give focus effectively to the analysis. These include:

- Is there equipment commonality (i.e., does the issue arise on one production system, on a particular group of production systems, or on many varied production systems)?
- Is there material commonality (i.e., does the issue arise in connection with one production material, a particular group of production materials, or with many varied production materials)?
- Is there temporal commonality (i.e., does the issue arise consistently at a predictable time or in proximity to an identifiable event)?

If a single area of commonality can be discerned then analysis should focus on related causal factors. If more than one area of commonality can be discerned then it is likely that multiple causal factors are interacting to generate the problem.[3]

As causal factors come to be suspected, supporting information can and should be gathered through equipment inspections, process evaluations and materials assessment and testing.

Equipment inspections can be useful for documenting the condition of screws, dies or heads, and other major components where poor materiel condition can lead to the buildup of contamination.

Reviews of process parameters can disclose areas where material may be subjected to excessive temperature or to relatively high temperature for excessive periods of time. (This can include shutdown/startup cycles or cases where material inventory in the barrel exceeds the norm, thus leading to excessive residence time.)

Materials assessment and testing may show (or confirm) that either melt rheology characteristics or thermal sensitivity is contributing to the development of difficult purging issues.

A catalogue of possible causal factors related to purging issues can be developed to aid in the analysis of each situation[4].

Development of the Solution Set

In considering the array of possible solutions that might be applied to purging issues, several guiding principles should be applied:

1st Principle: Success lies in controlling purging issues – not in eliminating them. No solution will completely eliminate equipment teardown. No product or technique will reduce time lost on changeovers to zero. There is, in short, no magic bullet.

Therefore the objective in developing the solution set is to generate implementable recommendations that will eliminate (to the extent possible) disruptive unscheduled teardowns and that will reduce time lost on color and mate-

[3] Instances of each situation come readily to hand. For example, if a single processing system, among a group of similar systems, exhibits problems and there is nothing unique about the materials processed by that system or its process parameters then one or more equipment-related causal factors would be suspected. The system would need to be examined for excessive wear, pitting or corrosion, or faulty instrumentation.

As a counterexample, suppose that machines of one design experience problems with one type of production material but not with other types, while machines of a different design do not share the problem. In such a case, a combination of causal factors – both equipment-related and material-related – must be suspected.

[4] One example of such a catalogue, in checklist format, will be found in the Appendix to this paper (or available for download at http://www.novachem.net). Users should carefully avoid the presumption that this (or any such) listing is exhaustive.

rial changes to an irreducible minimum. Perfection, while definable, is not achievable – but it can be approached as a limit.

2nd *Principle:* It is always better to eliminate the cause of an undesirable condition than to ameliorate its symptoms. At the same time it has to be recognized that real-world constraints may at a given time restrict freedom of action to those measures offering symptomatic relief.

In any event the solution set ought to include measures that address underlying causes even if such measures cannot be implemented in the near term. For example, if a pitted screw or a damaged die is leading to carbon contamination in the end product, the ultimate solution lies in rework or replacement of the component. If budgetary constraints rule out this action in the current fiscal period then an interim measure (such as purging with an effective commercial formulation at the first indication of the presence of carbon) can and should be evaluated. The ultimate solution will then remain on the agenda until such time as its implementation becomes feasible.

3rd *Principle:* If implementation and assessment are to be practical the solution set must incorporate explicit statements of realistic expectations. Success criteria, agreed upon by all those involved in the process, should be established relative to the situation prevailing in the past.

Success criteria should answer the question: "What constitutes a worthwhile improvement?" Failure to fulfill the expectations set by reasonable success criteria is cause for additional review and reconsideration of alternate solutions. However the fact that success criteria are achieved does not mean that the issue is fully and permanently resolved. The principles of continuous improvement can and should be applied.

The solution set may include equipment modifications, re-specification of materials, process changes and the introduction of new tools. (These are listed in descending degree of difficulty in implementation.)

If purging issues are attributed to equipment-related causal factors then equipment modification may be the most direct and effective way to address the issue. Replacement of worn or defective components is straightforward but may be economically difficult. When the causal factor is related to the design of the equipment (such as presence of a negative flow area in a die, or a problematic hang-up area in a blow molding head) remediation is much more difficult. The OEM may be either unable or unwilling to support proposed design changes.

Similarly, re-specification of material may be more or less implementable depending on circumstances. Where the processor has control over material selection, consultation with the resin supplier (or competing suppliers) may produce recommendations of alternate materials satisfactory for the end use but friendlier to the process. However, when the customer specifies or supplies the material there can be little freedom of movement.

Process changes are generally under the control of the processor. Changes in temperature profiles and cycle times or production rate are permissible given no ill effect on the final product. Choice of equipment (sized properly for the job) is equally at the processors discretion (although shop scheduling considerations may loom large).

One of the most significant process parameters (in its impact on purging issues) is the operating schedule of the equipment. In nearly every case, the ideal schedule is 24/7 – three shifts per day, seven days per week. Any deviation from this schedule introduces thermal stress on discrete volumes of resin that will eventually lead to degradation and contamination. The rapidity with which contamination appears will be a function of the thermal sensitivity of the resin and the frequency of shutdown/startup cycles.

Obviously, the adoption of a 24/7 schedule is a consequential economic decision. Rarely will purging issues alone be decisive for this measure.

Finally, new tools can be applied to the issue. Many formulated purging agents are available commercially. They come in various forms – liquid concentrates, powdered or pelletized concentrates, and ready-to-use pelletized mixtures. There are two primary categories of purging agents: chemical purging compounds and physical/mechanical purging compounds. The former operate via a thermally induced chemical reaction that directly affects the molecular structure of residual polymer, while the latter rely on differential melt viscosity and/or an abrasive character to displace residual resin and contaminants.

In general, chemical purging compounds tend to be somewhat more demanding on the user and somewhat more effective in purging performance; physical/mechanical purging compounds tend to be somewhat less demanding on the user while providing somewhat lesser purging performance.

In many cases, formulated purging agents can be very effective in ameliorating the negative productivity impact of color changes, material changes and the occurrence of contamination or degradation in production resin. Purging agents can be used to effect the removal of residual production resins, to provide a transition from high-viscosity to low viscosity materials, or to entrain and remove the products of resin degradation (gels, black specks, carbon) from systems.

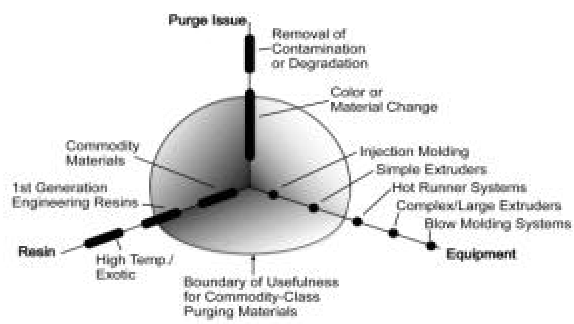
It is unlikely that any purging agent will accomplish the complete removal of contamination from a badly contaminated processing system. In cases where contamination is severe the more fruitful course is to tear down and clean the equipment mechanically and then to implement solutions that will prevent recurrence of the situation.

In such cases purging agents will be most effective at shutdown, where their role is to remove residues of thermally sensitive materials from the system before they can acquire enough heat history to cause degradation.

Selection of the most beneficial product to address any particular purging issue can be difficult but some generalities can be adduced:

- Issues should be addressed using the type of product that offers sustained satisfactory results at the lowest overall cost. Overall cost must be evaluated in terms going well beyond the unit price of the product. Evaluation should include the direct cost of the material, peripheral costs associated with its use, and the operational considerations associated with use (e.g., complexity, undesirable side effects such as odor, health, safety and environmental issues).
- There are degrees of difficulty associated with purging issues along several axes (see the figure, below). The "axes of difficulty", and examples of variants thereon (from more challenging to less challenging) are:
    - Equipment Type – extrusion blow molding systems, large or complex extrusion systems, hot manifold systems, injection blow molding systems, simple extrusion systems, simple injection molding systems;
    - Resin Grade – exotic resins (PEEK, PEI, etc.), engineering grade resins (PC, PA, ABS, etc.), commodity grade resins (PP, PP, PS, PVC);
    - Purge Issue Type – carbon or other contaminant, dark-to-light color change, material change.

  Along each axis, the more difficult purges will probably require use of higher performance purging products. Less difficult purges will be accomplished satisfactorily using less sophisticated products.



In cases where purge issues are expected to arise from the "challenging" end of one or more of these axes, solutions are more likely to be found among "high performance" purging agents. In "less challenging" situations it is likely that "commodity grade" purging agents will be sufficient to the need.

Implementation of the Solution Set

Once the measures constituting the proposed solution set are agreed upon, it is highly desirable that they be implemented as a "pilot" program. In an ideal situation two similar systems will be observed – one on which the solution set is tested and one that acts as a control.

This arrangement allows the unambiguous attribution of performance changes to the implemented solution set, to the exclusion of external environmental factors.

In cases where a "test vs. control" method cannot be employed (e.g., a case where only one large system is involved) then prior performance must serve as the control. In such cases it is extremely important that this performance level is accurately and precisely documented and that environmental and operational variables are consistent.

The duration of the evaluation period needs to be considered carefully. A single episode is not likely to be determinative of either success or lack thereof. The evaluation must extend across a number of complete operational cycles to establish whether sustained satisfactory results have been achieved. The extent of the evaluation period will vary as a function of operational parameters, but in most cases it ought to be on the order of a month.

A carefully prepared solution set will normally deliver observable improvement on the test system relative to the control system on the first operational evolution. It may not, however, deliver results immediately that reach the level of previously agreed upon success criteria. A learning curve is to be expected.

A month-long multi-cycle evaluation permits the solution set to be fine-tuned in response to interim results. Each operational evolution conducted during the evaluation period should be reviewed immediately to identify desirable refinements.

As this process continues, care should be taken to change only one thing at a time. Only in this way can any improvement attributable to the change be isolated.

At the end of the evaluation period the results achieved should be documented in a manner that parallels the initial step of describing the current situation. This will facilitate rigorous assessment of the results[5].

Assessment of the Results

It should now be a straightforward matter to assess the results achieved by comparing data collected for the test system at the end of the evaluation period with data compiled at the start of the program. Reductions in the impact of purging issues on system productivity should be readily identifiable and quantifiable. Every effort should be made to project the ultimate result of adopting the solution set in terms of plant-wide annualized dollar savings.

Results should be directly comparable with agreed upon success criteria. There need be no ambiguity concerning what has been achieved provided that each preceding step has been applied rigorously.

Assuming the assessment concludes that all reasonable expectations have been achieved, it is important to provide a plan for expanding application of the solution set beyond the initial test system. In cases where it cannot reasonably be assumed that comparable results will be achieved on disparate systems, further evaluations may be necessary.

As the solution set (or developed variants) "rolls out" plant-wide, it is important to monitor performance on an ongoing basis. As environmental variables change over time, that which was successful may become marginal. Ongoing vigilance is necessary to sustain peak productivity. It is therefore appropriate to re-evaluate the adequacy of methods used in response to purging issues on a periodic (perhaps annual) basis.

[5] The same data should be collected and presented in the same format (again, the information can be compiled conveniently using a data collection sheet such as the one shown in the Appendix to this paper (or available for download at http://www.novachem.net)).

If any trend of deterioration in productivity attributable to purging issues is detected, it will be time to apply once again the method outlined in this paper.

An Example of the Approach in Action

A large operator of blown film extrusion systems sought a better way to accomplish material transitions, system clean-ups and equipment protection on extrusion line shutdowns.

The operator previously had used various production materials and commercially available physical/mechanical purging agents to accomplish these tasks.

Description of the Past Situation

The equipment involved were large blown film systems that normally operated 24/7. Some systems were coextrusion (multi-layer) designs. Materials processed included LDPE, LLDPE and various adhesive and barrier materials.

The operator normally relied on the succeeding production resin or on a physical purging compound to facilitate material changes in its equipment.

Three to four times each month gels and specking would contaminate subsequent production. The contaminants would persist for three to four hours and regularly resulted in loss of the bubble. In the most severe cases, these materials would hang up in low flow areas of the die and degrade, creating die lines. This would require a teardown of the die for manual cleaning that took the system out of production for one to two days. Unscheduled teardowns of this sort were needed about once each month.

Analysis of the Problem Set

The problems described above occurred on all production systems and were experienced with various production materials but most especially after heat sensitive materials had been run.

It was postulated that in many cases (particularly in cases involving removal of ethylene vinyl alcohol (EVOH) and Surlyn®) the techniques and materials in use were inadequate to remove all of the prior production material from the system being purged.

Development of the Solution Set

The operator decided to evaluate a chemical purging compound to facilitate material changes. It was considered probable that this type of material would be more effective in removal of previous production resins compared with the purging agents previously in use.

The success criteria were established as 25% reduction in time required for material changeovers and 50% reduction in the incidence of unscheduled teardown.

Implementation of the Solution Set

One large production system was torn down and mechanically cleaned. Thereafter, the chemical purging compound was used on every shutdown and changeover on that system.

After about a month it was noted that this had led to significant improvements. These included:

- Avoidance of contamination associated with material changeovers. In contrast with other systems, where introduction of a new production resin often led to hours of contamination, now a one-hour purge cycle using the chemical purging compound normally provided a trouble-free transition on the test system.
- Elimination of severe contamination on system start-up. Using the chemical purging compound for shutdown of the test system provided start-ups that exhibited specking for minutes instead of the hours seen with other shutdown methods.

Assessment of the Results

Because changeovers from EVOH and Surlyn® could now accomplished more efficiently, 9 to 12 system hours per month of productivity were recovered. In addition, frequency of teardown for manual cleaning has been reduced by approximately 2/3. This results in recovery of from 2 to 4 system days of productivity each quarter.

Assuming median values for these savings and annualizing the result shows that the operator has recovered about 400 system hours per year of productivity. Since the charge rate for these systems averages $450 per hour, the recovered value attributable to this program is approximately $180,000 per year. The cost of the chemical purging compound was about equal to the amount previously expended for physical purging agents.

Appendix: Some Useful Tools

On the following pages we reproduce some tools that processors may find useful in experimenting with the approach outlined in this paper. They include:

- Purging Issues Response Methods – Data Collection Sheet
- Purging Issues Causal Factors Checklist
- Purging Methods Cost Comparison Sheet

NOVACHEM

PURGING ISSUES DESCRIPTION/DATA SHEET

Fill out a separate sheet for each purging situation that needs to be analyzed.

Equipment Variables

Equipment Type: Injection Molding ❑ Extrusion ❑ Ext. Blow Molding ❑ Other_______________

Equipment Configuration(See Note: 1) ____

Equipment Size(2) ____

Peripheral Equipment(3) ____

Unusual Characteristics/Known Problems(4) ____________________________________

____

Operating Parameters

Operating Schedule: 24/7 ❑ 24/5 ❑ Daily Shutdown ❑ Other ________________

Temperature Profile: (Throat)_____/_____/_____/_____/_____/_____(Die/Head/Nozzle) (°F)/(°C) (5)

Material Residence Time: ____ (6)

Maintenance History

Frequency of teardown: __________________ Time since last teardown: ______________________

Condition of components: ____

Production Materials Properties

	Preceding Production Material	Succeeding Production Material
Resin Type		
Melt Flow Index/Shore D Rtng.(7)		
Recc. Proc. Temp. Range		
Critical Temperature (if any)		
Color		
Additives		
Regrind %'age		

Purge Situation

Purge Type: Color Change ❑ Material Change ❑ Contamination Removal ❑ Shutdown ❑

Frequency: (How often does this situation arise) per system? ___________ plant wide? ___________

Timing: (When does this situation typically arise?) ____(8)

Purge Situation Response

Describe the normal response to this purge situation: ____

____

____

What products are used? __________________________________ What Qty.? _________________

What side-effects (if any) occur? [9] ____

____

Impact on Productivity

	Per Occurance	Per Year
Cost of Lost Machine Time[10]		
Cost of Excess Labor[11]		
Cost of Lost Material Value[12]		
Cost of Materials Used[13]		
Cost of Foregone Profit[14]		

Other Comments

____

____

Notes

(1) Further describing equipment type, e.g., for injection molding note hot manifold; for extrusion note single or twin screw and die type (i.e., blown film, sheet, strand, profile, etc.); for ext. blow molding note continuous, reciprocating screw or accumulator and number of heads.

(2) Include careful estimates of system volume including screw and barrel, as well as all downstream components and plumbing. State in terms of pounds of resin needed to fill the system.

(3) Note such items as melt pumps, static mixers, automatic screen changers, etc.

(4) Note areas of hang-up or accumulated contamination based on observations made in prior teardowns.

(5) Indicate either °F or °C by crossing out the other.

(6) Estimate the time an element of resin spends in the machine during normal production.

(7) For PVC note Shore D hardness rating; for other resins note melt flow index per ASTM D1238 including conditions (temperature and load) at which it is derived. (See the material specification sheet for this information.)

(8) Note what other events are associated with the issue, or when in the production cycle it often arises.

(9) Note such items as objectionable odors, damage to equipment, etc.

(10) Hours out of production times machine hourly rate. Normally includes production labor.

(11) Man-hours in excess of normal production labor times hourly rate.

(12) Pounds of resin used but not made into good product, times the difference between cost and salvage value.

(13) Pounds of any purging agent used times cost per pound.

(14) Profit that would have been realized from product made during the period when the system was unavailable, had the purging issue not arisen.

POSSIBLE CAUSAL FACTORS IN DIFFICULT PURGE SITUATIONS

Review all of the following possible causal factors in assessing each purge issue. Bear in mind that this listing should not be considered exhaustive.

1. Dark-to-Light color changes

1.1. Unidentified or inaccessible hang-up areas

1.1.1. Stagnation points .... ❒
1.1.2. Low velocity areas .... ❒
1.1.3. Flow path expansions/contractions .... ❒
1.1.4. Changes in flow direction .... ❒

2. Material changes

2.1. Known adverse relationship in melt viscosities

2.2. Unidentified or inaccessible hang-up areas

2.2.1. Stagnation points .... ❒
2.2.2. Low velocity areas .... ❒
2.2.3. Flow path expansions/contractions .... ❒
2.2.4. Changes in flow direction .... ❒

3. Removal of degradation/contamination

3.1. Material related factors

3.1.1. Heat sensitive resins .... ❒
3.1.2. Heat sensitive additives .... ❒
3.1.3. Quality issues in raw materials (gels or carbon present) .... ❒

3.2. Equipment condition/design related factors

3.2.1. Worn or pitted metal surfaces .... ❒
3.2.2. Damaged plating .... ❒
3.2.3. Faulty instrumentation or control components .... ❒
3.2.4. Persistent material hang-up at stagnation points, flow path changes or low velocity areas. .... ❒
3.2.5. High-shear screw design overstressing material .... ❒

3.3. Process related factors

3.3.1. Excessive heat history due to shut-down/start-up cycle .... ❒
3.3.2. Excessive residence time due to use of oversized equipment .... ❒
3.3.3. Melt temperatures at or near critical levels .... ❒

NOVACHEM

Purging Methods Cost Comparison Sheet

	Method #1	Method #2	Method #3
Machine Time Lost	________Hours	________Hours	________Hours
Machine Rate	$________/Hour	$________/Hour	$________/Hour
Cost of Lost Machine Time			
(Time X Rate)	$________	$________	$________
Teardown Labor	_____Workers	_____Workers	_____Workers
Teardown Time	_____Hours	_____Hours	_____Hours
Teardown Labor Rate	_____$/Hour	_____$/Hour	_____$/Hour
Teardown Labor Cost			
(Workers X Time X Rate)	$________	$________	$________
Material Usage			
Resin Consumed	________Lbs.	________Lbs.	________Lbs.
Resin Price	$________/lb.	$________/lb.	$________/lb.
Credit for Salvage/Regrind Value	-$_______/lb.	-$_______/lb.	-$_______/lb.
Net Unit Cost of Resin	$_______/lb.	$_______/lb.	$_______/lb.
Total Cost of Resin Consumed			
(Lbs. X Net Cost/lb.)	$________	$________	$________
Purge Compound Consumed	________Lbs.	________Lbs.	________Lbs.
Purge Compound Price Price	$________/lb.	$________/lb.	$________/lb.
Total Cost of Purge Compound			
(Lbs. X Net Cost/lb.)	$________	$________	$________
Purging Labor	_____Workers	_____Workers	_____Workers
Purging Time	_____Hours	_____Hours	_____Hours
Purging Labor Rate	_____$/Hour	_____$/Hour	_____$/Hour
Purging Labor Cost			
(Workers X Time X Rate)	$________	$________	$________
Lost Production Profit	$________	$________	$________
Miscellaneous Costs	$________	$________	$________
Total Cost per Event	$________	$________	$________

NOVACHEM
955 Connecticut Avenue
Bridgeport, CT 06607 USA

Telephone: 1-800-762-3984 – 203-366-4081
Telefax: 203-367-0648

Internet: http://www.novachem.net
e-mail: info@novachem.net