COMPOUNDING AND PROCESSING PVC:
GENERAL PRINCIPLES OF PLANT OPERATION FOR OPTIMUM PROFITABILITY
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ENCYCLOPEDIA of PVC - VOLUME IV
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I. INTRODUCTION:

Other chapters of the Encyclopedia of PVC that discuss the compounding, processing, and testing of PVC products have as a common goal an optimized scenario which directly affects production efficiency, product quality and therefore plant profitability.

The entrepreneur, owner, general manager, purchasing manager, sales manager, production manager, quality control supervisor, shift foreman, and yes, even the operators and technicians on the third shift - all must be concerned with achieving the best possible results within their areas of responsibility in order to insure that the PVC plant meets or exceeds its goals in customer satisfaction. No matter what the finished product is, consistent, on-time delivery of a high quality, uniform product at a low cost and fair price will insure any plant’s competitive stance in its market arena, and many happy customers. Satisfying a customer’s needs promptly and competitively is, after all, the main reason the PVC processing plant exists!

The purpose of this chapter, therefore, is to address those factors that will enable any PVC processing facility to operate at its most efficient and profitable level.

II. HISTORIC PERSPECTIVE:

A reflection over the past 50 years’ growth of the PVC processing industry is instructive, especially as the industry moves into the next century with new products and new markets continually evolving.

Growing from just a few hundred million pounds in the late 1940’s and early 1950’s to over 13 billion pounds in 2000 (U.S. Domestic), the vinyl processing industry has demonstrated over and over again its imagination, innovation and grit in weathering many challenging periods, successfully resolving a host of problems such as:

* The vinyl chloride monomer (angiosarcoma) crisis.
* The phthalate ester “crisis”.
* The attacks of the cast iron and ductile iron pipe industry on PVC pipe.
* Fire, smoke, HCl emission issues arising from the Beverly Hills Nightclub, MGM Hotel and Air Canada fires - PVC in wire, cable and plenum products under attack, in fact, even on trial in court.
* Increasing pressures to remove toxic and heavy metals (cadmium, lead) from PVC compounds.
* The “chlorine issue” - specifically Greenpeace attacks on PVC’s production and use as a major source of dioxin, based upon non scientific or pseudo scientific “evidence”.
* Increasing regulatory constraints of OSHA, EPA, state ‘right to know’ laws.

Reflect for a moment on what has transpired with PVC over the last 50 years: A polymer
that by itself is brittle and horny, has very high melt viscosity, easily degrades under heat and shear to evolve corrosive HCl, tends to stick to hot metal surfaces, nevertheless, has exhibited remarkable growth in a wide variety of flexible and rigid products that cut across virtually all sectors of our society:

**Transportation:** Auto, aircraft and mass transit interiors, seating, dashboards, auto body-side moldings, sealants, wiring harness, foamed gaskets.

**Building and Construction:** Piping and fittings, siding, window profiles, flooring, roofing membranes, wall covering, fencing and marine docking.

**Electronics and Communications:** Wire and cable insulation, rigid conduit, fiber-optic cable conduit, molded computer and instrument housings.

**Packaging:** Film for meat and produce packaging, bottles, clear sheet (thermoformed).

**Medical:** Blood bags, tubing, surgical gloves, etc.

**Personal and Leisure:** Footwear, hose, fishing worms, dipped tool handles, refrigerator gaskets, pool liners, foamed flotation gear, powder coated racks and shelving, outdoor furniture.

From the above incomplete listing we see polyvinyl chloride products encompassing properties as diverse as a wiggly fishing worm and a rigid, high impact strength computer housing, or window profile. Why? The versatility of PVC - its ability to respond so well to a host of additive ingredients (plasticizers, modifying resins, process aids, lubricants, stabilizers, fillers, blowing agents, and so on) to achieve such a wide range of attractive physical and visual properties at reasonable cost - this versatility is unmatched among the large volume, if not all thermoplastic polymers.

Vinyl’s growth has been healthy, at times vigorous, and occasionally controversial, but never dull!! There always has been room for honest differences of opinion, such as:

- Pellet vs powder blends (for extrusion, injection and blow molding,
- Vented, long L/D vs non vented shorter L/D extruders,
- Single screw vs multi screw extrusion,
- Parallel vs conical twin vs four screw extrusion,
- Lead vs tin stabilization of pipe,
- “One pack” additive system vs separate components,
- Lubrication theories and practice: internal-external ratios for single and twin extrusion; is calcium stearate internal, external, or something else?
- Extrusion blow vs injection blow molding,
- Octyl/methyl tin vs calcium-zinc stabilization of food grade vinyl,
- High intensity power blending: single, double or triple batching vs ribbon blending cold-mix,
- Profile vs post-formed siding extrusion,
- Weathering: laboratory results vs outdoors, best test sites?
Industry agreement on minimal acceptable standards?
Use of TiO2: U.S. vs European formulation practices.
Impact testing: best methods?
Torque Rheometer: correlation with real-world processing or not?
Smoke and flame testing: real world correlation or not?
Many of the differing opinions cited above have been resolved....some may never be resolved! However, the unique versatility of PVC, combined with the fact that only 43% of its composition relies on petroleum feed stocks, and its excellent cost-property profile, will insure PVC’s continued growth well into the 21st century...not only with expanded current uses, but as new products and markets, yet unimagined evolve, Greenpeace notwithstanding.

III. PVC’S PROCESSING OPTIONS:
With PVC’s unmatched versatility, as described in Section II above, its processing can encompass one or more of the following operations, all of which are discussed in other chapters of this encyclopedia:

Compound Production: (Vol. III, Chapter 1-4)
- Flexibles and rigids, powder blends, pellets, plastisols, organo-sols, latex.
Calendering: (Vol. IV, Chapter 3)
- Flexibles and rigids, film, sheet, foam, coated fabric or paper.
Plastisol Processing: (Vol. IV, Chapter 4-6)
- Coating, casting, roto and slush molding, dipping, foaming.
Blow Molding: (Vol. IV - Chapter 1-2)
- Extrusion or Injection blow molding.
Compression Molding: (Vol. IV, Chapter 2)
Extrusion: (Vol. IV - Chapter 1)
- Pipe, profile, sheet, flexibles and rigids, direct powder extrusion, pellet extrusion, single screw, twin screw, co-extrusion, foaming and foamcore.
Injection Molding: (Vol. IV - Chapter 2)
- Flexibles and rigids, pellet or powder injection molding.
Direct Powder processes: (Vol. IV - Chapter6)
- Fluid-bed, roto or slush powder molding, electrostatic spray.
Secondary Processing/Finishing: (Vol. IV - Chapter 7)
- Post-expansion of foam, printing, laminating, embossing, thermo-forming, vacuum forming, fabricating (solvent welding, heat sealing, etc.).
IV. RIGID PVC EXTRUSION SELECTION:

It would not be possible to cover all of the above processing options in this single chapter on operating a PVC plant for profit.

Therefore, for purposes of illustration, further discussions of optimum plant operations will use a typical rigid PVC twin screw extrusion (from powder dry blend) plant scenario. Why extrusion? Why rigid PVC? Of the over 13 billion 2000 pounds of domestic U.S. PVC consumption, over 70%, over 9 billion pounds were squeezed through extrusion lines to produce the following rigid vinyl products:

- Potable water pipe (pressure rated)
- Drain, waste,& vent pipe
- Sewer pipe (both storm and sanitary)
- Large diameter spiral wound piping
- Irrigation pipe
- Electrical conduit
- Fiber-optic cable conduit
- Livestock (hog) slats
- Foam-core pipe
- Siding
- Foam sheet
- Solid and clear sheet (for vacuum and thermo-forming)
- Window profile
- Solid and foamed profile
- Fencing and Marine Docking
- Furniture
- Wood flour-filled profiles - just emerging in new markets.

As the discussion of our hypothetical rigid PVC extrusion plant progresses, please keep in mind that the factors found necessary to achieve optimum production efficiency and product quality in extrusion are also essential - without exception - in all other PVC production operations. Terminology, equipment, and formulations may differ, but the essence of what is necessary at each stage of any process is strikingly similar. Thus, as we reference the rigid vinyl extrusion operation, keep in mind that parallel factors also exist for calendaring, injection molding, coating, and all other vinyl compounding and processing operations. It is crucial to note that decisions taken at each stage of developing a PVC processing plant will have ultimate bottom line effects upon profitability… but fortunately most of these decisions, while perhaps costly, are reversible if they prove wrong. Let’s examine some of the factors, posed as key questions that affect the decisions in setting up and profitably running any PVC processing operation. With extrusion used as our example, some answers to these questions then follow. You, the potential entrepreneur will eventually develop your own answers.
V. SITE SELECTION-GENERAL PRINCIPLES:
The entrepreneur or owner must ask and answer a number of basic questions which will affect where the new plant will locate. Depending on funding, do you want a new plant, or an existing facility? What are you going to produce? Why? For whom? Where are your customers? Where are your raw material suppliers? Who and where is the competition? How will you sell and distribute your products? A commissioned market survey should help provide these answers. Are there any incentives (i.e. tax abatements) to locate here? Will any local restrictions, zoning laws or regulations play a role in selecting this location? What are the costs and availability of utilities; water, power, and waste disposal? Is there a good supply of skilled labor available? Union or non-union? Does the site have access to rail siding and trucking? Will this location be able to attract professional production and laboratory personnel? Availability of commercial trucks, machine shops, and spare parts outlets also needs to be considered.

What will the scope of operations be at this site? Production and quality control only? Production, quality control and a product development laboratory? Will this site also contain administrative, sales and marketing functions, or corporate headquarters?

VI. PLANT LAYOUT-GENERAL PRINCIPLES:
A:- What plant design should one use? It is obvious that a rational, smooth production flow pattern or sequence will contribute significantly to plant efficiency: Incoming raw materials stored at one end of the plant;
Material movement to weighing and blending areas;
Compound transport to processing lines;
Processed products downstream moved to post-finishing operations if needed, or packaged, bundled and moved to finished goods inventory;
Shipment to customers...’in one end and out the other’ would be the ideal, if site topography will permit.

A myriad of questions still remain to be answered to arrive at a finished plant layout blueprint.

B:- How basic (vertically integrated) will this plant be? Will ‘store bought’ compounds be processed? Or will in-house blending and compounding, or even formulation development take place? What is the break-even point in production volume that will justify in-house compounding? (Currently for rigid PVC extrusion, it’s about 8-10 million pounds per year. This volume can vary and is dependent upon costs of blending equipment vs. the differential between PVC resin pricing and merchant compound pricing.) After primary processing, will any secondary post-finishing or fabrication steps be performed?
C:- How big will this plant be? How many production lines are needed initially, and will provisions for future expansion be included in the initial design?

VII. GENERAL PLANT OPERATIONS:
A:- If in-house blending is planned, how will in-coming raw materials (resin, plasticizers, fillers, micro-ingredients) be handled? Is the proposed production volume large enough to justify bulk rail or truck shipements of PVC resin, plasticizers, fillers, even stabilizers? Or will super sacks, totes, drums, bags, and gaylord boxes be used for the major ingredients as well as the micro ingredients?

B:- Whether ‘store-bought’ or blended in-house, how will compound be handled prior to primary processing? Will powder blends or pellets be stored in silos for transport to processing lines, or moved directly to production in gaylord boxes? Will liquid plastisols or organosols be stored in bulk tanks or in drums? Will a multi-stage compounding operation be required? i.e.: powder blend---->banbury------>mill/extruder--->to calender. Or: powder-blend---->extrusion/pelletizing---->to injection molders or to product extrusion lines.

C:- When compound is delivered to the primary processing lines (whether pelletizer, extruder, injection or blow molder, calendar, spread coater, rotor molder, etc.) a basic production decision must be made. Will the plant operate on a round-the-clock, three shifts, and seven day/week basis? Customer or market needs as well as economics of the product and competitive strategies will affect this decision. Obviously, the more pounds, feet, or widgets per hour, shift, month, year, the lower the fixed cost allocation per product unit will be... which will translate directly to enhanced profit margins, provided a market need exists to justify this production level.

D:- Down-stream from the primary processing step, questions of secondary or post-finishing operations are addressed. What else must be done to complete the manufacturing process at this plant? Or will these operations be completed off site, at another location, or by the customer? Continuous processes (extrusion, calendaring, coating, casting) require marking, cutting to length or roll diameter, and also may require embossing, printing, post-foam expansion, laminating, thermoforming, vacuum forming, solvent welding, or heat sealing. Intermittent processes (injection molding, blow molding, roto or slush molding, powder molding, dipping) may require trimming of excess flash (which hopefully can be reground and reprocessed.) Further fabrication or assembly may then be needed.
E:- Whatever the end-products of this plant, how will they be packaged for shipment? If the outgoing products are pellets, powder blends or liquid plastisol compounds, will bulk rail or trucks be used? Or will totes, gaylord boxes or drums be the packages of choice? Depending on their shape and size, the other vinyl products may be inspected, bundled, wrapped, boxed, weighed and tagged. At this point, the question of inventory is addressed. Will production inventory remain on-site? Indoors? Outdoors? Or will ‘just-in-time’ shipment to customers be required?

F:- A very important question to be answered, particularly from a bottom-line profit point of view is: how will scrap or regrind be handled? The ability to reprocess usable scrap into “on-spec” production may mean the difference between profit and loss in the plant operation. Some processes like laminates, coated fabric or fused plastisol products cannot utilize their scrap back into the same process. However, most flexible and rigid PVC processes will generate a certain percentage of their total output as re-usable scrap...from sprues, edge trim, flash, start-up material and off-sized production. How will this material be segregated, chopped or pulverized and re-used?

   Edge trim from calendared, flexible vinyl can be fed directly back to the calender. Chopped or pulverized regrind (flexible and rigid) can be blended to a certain percent (usually 10%-50%) with virgin compound for processing, depending on finished product specifications.

   Pulverized regrind is gaining favor in rigid PVC extrusion plants, either blended with virgin powder-blend, or sometimes run as 100% re-grind in low-end specification products, like sewer pipe or ‘J’ channels for siding systems.

   A certain (hopefully very low) amount of scrap can be generated by burn-ups, caused by power failures or malfunctioning of blending or processing operations. Obviously this material should not be allowed to contaminate the normal ‘clean’ scrap. Whether by power failure or equipment malfunction, no coffee breaks should be taken with static, molten PVC in the mixer or extruder! If a burn-up should occur, there is no reason to panic. Evolved HCL is corrosive and very irritating, but not highly toxic. Good ventilation is a must, as well as quenching the burning PVC in cold water. Long term PVC operators are known to have clear sinus cavities due to occasional whiffs of HCL!

G:- Any discussion of general principles of profitable PVC processing would be incomplete without considering the importance of monitoring the materials balance of the plant. Whether daily, weekly or monthly (a quarter or a year is too long without knowing), an owner or general manager should be able to equate total pounds of raw materials received, plus material in-process (compounded), plus usable re-grind, plus product inventory with total pounds shipped out the door... any difference being spillage, floor sweepings and unusable scrap.
VIII. SPECIFICS OF A PVC EXTRUSION PLANT:
Using a prototypical rigid PVC extrusion facility as our example, let’s explore a little more closely the specific factors that will contribute to a profitable operation.

This plant will extrude rigid PVC products from in-house mixed dry-blend PVC compounds. The products could be pipe (2 to 20” diameter), spiral wound pipe, fence posts and rails, siding and accessories, or window profiles or custom profiles, or sheet.

A. Site Location: Where is the plant located? Large to medium pipe producers tend to have several smaller (4-8 extrusion lines) plants located to serve a majority of their customers within a 500-700 mile radius, since shipping a truckload of pipe is mostly air, thus very freight sensitive. They also tend to concentrate their business on either pressure pipe, sewer, drain-waste-vent, irrigation, or conduit markets. Profit margins also can be very thin in the pipe business!

Siding and window or custom profile extruders tend to have much larger plants (15-40+ extrusion lines) due to the wider variety of sizes, shapes and colors they must offer in their line. These plants also need to be tied closely with their distribution channels, thus are often found in or near major metropolitan areas.

In any case, the plant preferably will have access to a rail siding and also have bulk truck and truck docking facilities. Water and power availability and reliability will have been checked out thoroughly. If power outages occur more than rarely, an in-plant generator should be factored into the capital budget!

How big will the plant be? Our design will call for a 100,000 sq. ft. (200 X 500 ft.) facility to house the equipment as described below, in addition to offices, laboratory, shower and lunch areas.

B. Plant Layout:
1. Materials Handling: Our extrusion plant will have a PVC resin silo for bulk rail resin delivery, and three silos for filler(calcium carbonate) and powder-blended compound storage. Space is allocated for future addition of two more silos. Liquid organotin stabilizers will arrive in metal tote tanks, and other micro ingredients (fillers, TiO2, modifier resins, lubricants, and pigments) will be in bags or gaylord boxes. All will be stored indoors near the blending area. Astute purchasing will strive to develop a strong relationship with primary suppliers and second sourcing as well. Bulk and full truckload shipments, especially if augmented by a long term contract where possible; offer the promise of lower material costs and more importantly, a measure of price stability.

Control of raw material inventory is an important component of a profitable, efficient production operation. On-time delivery from suppliers is certainly key, but it is wise to have at least a week’s ‘cushion’ of materials on hand in case the scheduled deliveries are delayed unexpectedly. Inventory rotation should be on a FIFO (first in - first
out) basis as it moves to the blending area. Bulk silos operate in this manner anyway and micro-ingredients should be used likewise. There is no good technical reason to use a LIFO (last in - first out) basis inventory method, but it is an option if financial reasons dictate. Above all, avoid the FISH (first in - still here) method!

2. The Production Year: Current practice among some extrusion operations is to achieve a maximum “year” of 350 days (@24hrs./3 shifts = 8400 hrs.) Our estimates will be more conservative.

For a continuous operation like extrusion to run efficiently, plant shutdowns and start-ups should be minimized. Therefore, this plant will run on three shifts, 24 hours per day, seven days a week for 50 weeks, (with a two week shut-down for major maintenance). However, up to two shifts per week, (16 hours) will be made available for routine maintenance, die changes or possible power outages. Thus, our production year becomes: 24 hours per day X 7 days = 168 hours per week; 168 hours - 16 hours = 152 hours per week X 50 weeks = 7,600 hours per year, which we will label the ideal, full production year. However, real world economics and weather may dictate slow-downs (2 or 1 shifts), or even occasional plant shut-downs. Therefore, we will base production outputs, costs, and profit projections on an “80% of ideal” rate, or 6,080 hours per year, a conservative worst-case scenario.

3. Blending: A 1,200 liter high intensity mixer and 3,600 liter cooling mixer will be used to make 1,000 pound single-mix batches of PVC dry-blend, or 2,000 pound double-mixed batches if needed.

Space is also available for a second blender/cooler set up to be added. The blender will be fed by automated weigh-hoppers for PVC resin and filler from the silos, and a metering pump for liquid tin stabilizer from totes. All other micro ingredients may be hand-weighed or automated, and added in the appropriate sequence, and the batch dumped to the cooling mixer when it reaches the chosen ‘drop temperature’.

The cooler may contain an equal amount of PVC resin, or resin plus an amount of pulverized re-grind, if ‘double-batching’ is necessary to increase compound production capacity. The cooled batch is then conveyed to the compound silo for later transport to extrusion lines.

The capacity of this blending facility, based on 1,000 pound batches, 6 batches per hour, (conservative 10 minute cycle used...actual cycle closer to six minutes), and a 7,600 hour year is: 6,000 pounds per hour X 7,600 hours per year = 45.6 MM pounds per year of compound; at 80% use, this becomes 36.5 MM lbs. If double-batch mixes were used (2,000 lbs. batches), capacity would jump to 91.2 MM lbs.(or 73MMlbs.at 80%).
4. **Extrusion:** The plant will initially contain eight twin screw extrusion lines, with space available for four more extrusion lines. Rigid PVC extrusion from powder blends is tailor-made for the counter rotating conical or parallel twin screw extruder. That choice was made years ago vs. single screw extruders (early 1970’s), based upon several factors:

* Single screw extruders deliver an average 10% overweight factor (to maintain minimum wall thickness or other dimensions) due to melt pulsations with each screw revolution.

* Twin Screw (conical or parallel) extruders act like gear pumps, with little variation in melt delivery, resulting in an average 5% overweight factor.

* That 5% difference in overweight (material given away) would amount to 3,000,000 pounds in a plant extruding 60 MM pounds per year! At a typical material cost of $.40/lb., $1.2 MM would be lost per year!

* Twin screw extruders consume much less power than single screw extruders to deliver the same output rates:

  1,000 lbs./hr. on an 86mm conical twin @ 75 HP
  1,000 lbs./hr. on a 6” single @ 200 HP

The eight conical twin screw extrusion lines chosen for our plant, and their production capacity based upon a 7,600 hour per year: (see figures):

<table>
<thead>
<tr>
<th>H.P. Drive</th>
<th>Each output, lbs/hr.</th>
<th>Combined MM lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 92mm conical twins</td>
<td>125</td>
<td>1,800</td>
</tr>
<tr>
<td>3 - 86mm conical twins</td>
<td>75</td>
<td>1,000</td>
</tr>
<tr>
<td>3 - 65mm conical twins</td>
<td>40</td>
<td>500</td>
</tr>
</tbody>
</table>

Annual Capacity 61.6 MM Lbs/yr. (or 49.3 MM lbs at 80% usage)

It is evident that with our blending capacity at 45.6 MM lbs./yr. on single batching, some ‘double-batching’ will need to occur to keep up with extrusion capacity. Although double-batching represents a compromise at best, by this process blending capacity can be increased to 91.2 MM lbs, enough to handle three or four additional extrusion lines.

Ideally, utilization of the maximum output rate, or production capacity of each extrusion line is the goal, providing the extruded product can be properly sized, cooled, handled down-stream, and sold. If the powder compound is properly formulated to the extruder (lubricant and stabilizer balance) so that the extruder screws, at near maximum RPM, can be flood-fed by the dosing hopper, and extruder amps (compound torque) and back pressure (compound melt viscosity) are within the ‘safe zone’, high output rates will result.

Twin screw extrusion is very sensitive to compound bulk density variations. As a ‘quasi-positive displacement gear pump’, a twin screw extruder will deliver a given
weight-per-volume-per-screw revolution of the incoming powder blend. Therefore, a higher bulk density powder will yield a higher output rate, at the same screw RPM. This is why some PVC resin producers are now introducing higher bulk density PVC resins, and also why—in the past—hopper ‘pre-heaters’ were used to increase powder blend bulk density.

Extrusion of regrind (see later) can be accomplished with a given level blended into virgin powder. Since regrind is already fused, it will not perform quite the same as virgin powder in the extruder barrel. Pulverized regrind certainly can be mixed with virgin powder, and extruded with no real problem. An alternate option, however, is to dedicate one or two extrusion lines to running 100% pulverized regrind into low-end specification products.

5. Plant Startup and Shutdown:

At times, it will be necessary to shut down the extrusion lines deliberately. As compound exits the extruder, a purge compound is fed in, which will totally displace production compound in the barrel, and then the die. All heat zones can then be turned off, and the die will contain the purge, which can be re-heated and pushed out upon a re-start.

A recommended purge compound for rigid extrusion:

- PVC - (K-65)................................. 100
- CACO3 (1-2 micron)...................... 100
- Calcium Stearate........................... 4.0
- 165 Paraffin Wax........................... 3.5
- Organotin mercaptide stabilizer........ 10.0
- Indicator pigment....................... as desired

6. Scrap Handling:

Modern PVC extrusion technology includes use of co-extrusion in a growing number of products:

* Dual durometer - flexible portions on a rigid profile
* Weatherable capstock on lower cost siding or window profile substrate.
* Foamcore pipe with solid I.D. and O.D. skins.

Typically, two extruders feed a common die-block with flow channels designed to obtain equivalent linear exit speeds from the die. Often a larger extruder will be fitted with a smaller ‘piggyback’ extruder (capstock or dual durometer), but co-extrusion may also consist of two similar sized extruders situated at right angles to feed a common die block.

The question of handling co-extruded regrind must be addressed, especially with dual durometer or foamcore products. Rigid vinyl diluted slightly with flexible vinyl, or foamed vinyl/skin blends can be pulverized and re-extruded, perhaps into low-end specification products.

To regrind, or pulverize, PVC scrap for in-plant re-extrusion is perhaps the largest
recycling usage of PVC that exists. As stated earlier, PVC processing will generate a certain scrap rate ...with extrusion it’s due to start-up material and off-dimension production. Average scrap rates can be in the 6-8% range for extrusion...if over 10%, serious steps need to be taken to reduce this rate in order to minimize bottom-line profit evaporation.

A good target would be to strive to achieve a 5% or lower scrap rate. Regardless of the amount of scrap, it needs to be handled in the most cost efficient manner. Older technology utilized scrap as chopped and screened regrind (about 1/4” average particle size). Pulverizes are now used, which further reduces the 1/4” chunks to a particle size close to that of virgin PVC powder blends. Thus, pulverized regrind easily can be blended with ‘virgin’ powder, or more likely, extruded as 100% regrind in low-specification products.

7. Downstream: Whatever products emerge from our extruder dies - pipe, siding and profile, sheet- all must be sized, calibrated, cooled, and cut to length in the downstream operation.

   Efficient cooling is essential, especially at today’s high output rates. Spray or mist cooling with chilled re-circulating water is preferred in most cases.

   Maintaining precise control of product dimensions - size, wall thickness or gauge-lies with the puller. Proper puller selection (single or multi-caterpillars, tire types) depends on size and shape of the profile. Chilled rolls are used for sheet. Ideally, puller controls should be duplicated on the extruder control panel, so an operator can match accurately the puller speed to the exit speed of PVC from the die. PVC’s melt ‘draw-down’ should be kept at a minimum so as to minimize built-in stress or memory upon cooling. Otherwise, subsequent heat exposure will trigger stress relaxation and product distortion or shrinkage.

   Rigid profiles and smaller pipes are normally cut to length with a circular saw (chop cut). A larger radial travel saw with chamfer cut is used for larger pipes, above 4” diameter. Sheet lines typically utilize a guillotine knife cutter.

   Once the products are cut to length and bundled, boxed or stacked, it is vitally important to keep accurate, up-to-date records of the weights and product codes of all on-spec production coming off each line. Whether for inventory or immediate shipment out the door, the exact amount and type of products is a key input to the ‘materials balance’ equation discussed earlier.

8. Capital Cost Estimate for Production Equipment

   The PVC extrusion plant as described above, with bulk handling, blending, regrind, extrusion and downstream equipment as indicated, carries an approximate price tag as follows:
<table>
<thead>
<tr>
<th>ITEM</th>
<th>M$/Each (est.’ 01 )</th>
<th>No. of Units</th>
<th>Total, M$(’01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silos</td>
<td>75</td>
<td>4</td>
<td>300</td>
</tr>
<tr>
<td>1200 L. Mixer/cooler</td>
<td>200</td>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>systems, all controls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto.- Weight/ Blending</td>
<td>100</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regrinder &amp; Pulverizer</td>
<td>80</td>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pre-Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$680</td>
</tr>
<tr>
<td>Extrusion Lines - Complete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For Pipe:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92mm conical</td>
<td>700 (8”-24”)</td>
<td>2</td>
<td>1,400</td>
</tr>
<tr>
<td>86mm conical</td>
<td>375 (4”-12”)</td>
<td>3</td>
<td>1,225</td>
</tr>
<tr>
<td>65mm conical</td>
<td>240 (1”-4”)</td>
<td>3</td>
<td>720</td>
</tr>
<tr>
<td>Pipe</td>
<td></td>
<td></td>
<td>$3,245</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$3,925</td>
</tr>
<tr>
<td>Or Siding &amp; Profile:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92mm conical</td>
<td>965</td>
<td>2</td>
<td>1,930</td>
</tr>
<tr>
<td>86mm conical</td>
<td>820</td>
<td>3</td>
<td>2,460</td>
</tr>
<tr>
<td>65mm conical</td>
<td>640</td>
<td>3</td>
<td>1,920</td>
</tr>
<tr>
<td>Siding</td>
<td></td>
<td></td>
<td>$6,310</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$6,990</td>
</tr>
<tr>
<td>Or Sheet:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92mm conical</td>
<td>1,100</td>
<td>2</td>
<td>2,200</td>
</tr>
<tr>
<td>86mm conical</td>
<td>875</td>
<td>3</td>
<td>2,625</td>
</tr>
<tr>
<td>65mm conical</td>
<td>530</td>
<td>3</td>
<td>1,590</td>
</tr>
<tr>
<td>Sheet</td>
<td></td>
<td></td>
<td>$6,415</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$7,095</td>
</tr>
</tbody>
</table>

**IX. ESSENTIAL FACTORS FOR QUALITY & PROFITABLE PVC EXTRUSION:**

A: **Quality Control Laboratory:** A well equipped quality control and development lab is essential to insure continuing production of top-quality products, continued satisfied customers, and continued profit growth. Such an investment in laboratory facilities will pay for itself in a short time by preventing a questionable raw materials’ use in production, improving dry blend quality, enhancing extruder output rates, and assuring shipments of quality controlled product to customers.

At the very least, certificates of analyses should accompany each lot of each raw material received. In-house lab tests on PVC resin might include:
Spot checks on stabilizers and lubricants also would include heat stability and fusion testing. A rejected and returned material shipment, with specific data documenting causes for rejection, should get prompt attention from the supplier!

A regular schedule of spot-checks on in-process dry blend, particularly bulk density and fusion/heat stability testing and color match checks, (before batch goes to silo), will help prevent any surprises on the extrusion lines.

In addition to raw material and compound quality control, the ability to improve or enhance the formulations used in production can translate directly to higher extrusion output rates and improved quality or lower costs. In order to run twin screw extrusion lines at optimum rates, the formulation (particularly the lubricant system) must be balanced to the particular extruder type. Also, attempts to lower material costs with higher filler levels need to be figured on a “pound-volume” basis since production is sold by volume (length) and needs to be priced by volume as well.

During extrusion processing, the quality control lab (and operators) have a major responsibility to monitor product quality, and take corrective action when needed. Such product properties as dimensional (wall thickness, size), physical (drop-weight impact, heat distortion, crushing, quick burst), appearance (smoothness, gloss, color), and chemical (dry acetone or methylene chloride fusion test, hot oil immersion) are monitored around the clock on all three shifts—usually at least every hour, or more often if problems occur. At 500 to 2,000 pounds per hour, quite a lot of off grade production can accumulate rapidly, for later regrind use. Time spent producing non-saleable products cannot be recovered and contributes to diminished profitability.

The importance of a good quality control function thus cannot be overstated. A well equipped quality control and development laboratory is not inexpensive. How much or how little to spend is dependent on management’s commitment to the complete quality control process, and also to the extent that product or compound development will occur. For our rigid PVC extrusion business, the following typical lab equipment and estimated costs are given:
LAB EQUIPMENT

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>ESTIMATED COST ('01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computerized Torque Rheometer with Type 6 mixing bowl &amp; roller blades</td>
<td>50,000</td>
</tr>
<tr>
<td>Lab. Extruder, Conical Twin Screw for Torque Rheo</td>
<td>33,000</td>
</tr>
<tr>
<td>Heat Stability Convection Ovens (3) Circulating Air</td>
<td>15,000</td>
</tr>
<tr>
<td>Colorimeter and Glossmeter</td>
<td>12,000</td>
</tr>
<tr>
<td>VHIT or Drop-dart Impact Apparatus</td>
<td>2,500</td>
</tr>
<tr>
<td>Vicat Softening or Heat Distortion Equipment</td>
<td>2,500</td>
</tr>
<tr>
<td>Quick Burst Pressure Test (Pipe)</td>
<td>3,000</td>
</tr>
<tr>
<td>QUV Indoor Light Stability Test</td>
<td>7,500</td>
</tr>
<tr>
<td>High Speed Lab Mixers and Scales</td>
<td>5,000</td>
</tr>
<tr>
<td>Bulk Density, Moisture, Dry Flow Test Equipment</td>
<td>1,000</td>
</tr>
<tr>
<td>P.C. for Storage and Retrieval of Q.C., Compound, and Production Data</td>
<td>5,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$136,500</td>
</tr>
</tbody>
</table>

B: Plant Maintenance:

As with the family car, all plant equipment should have a regular schedule of routine, preventative maintenance checks to assure a trouble-free, efficient plant operation. Cost of such a program is minimal compared to the alternatives. The adage, ‘pay me now or pay me later’ is as true for the PVC plant as the family car!

In addition to routine lubrication of bearings or gears, the following list of check points (probably incomplete) should be monitored on a regular daily, weekly or at least monthly basis. Malfunction of any one item on this list, if left unattended, will yield negative effects upon productivity, product quality, and ultimately the bottom line profit:

1. Blender--mixer--cooler:
   * Calibration of all automatic and manual weigh scales.
   * Mixer-blades and bowl wear.

2. Regrinder- pulverizer:
   * Sharpen blades.

3. Extruders and dies:
   * Build-up on hopper feed screw.
   * Clean drive motor air filters.
   * Clean vacuum traps. Good vacuum seals?
   * Zone temperature controllers - heat-cool cycles okay?
   * Heater bands working.
   * Proper screw-barrel alignment and clearance.
   * Screw and barrel wear - 10 and 2 o’clock positions.
     (wear points on barrel in counter-rotating twins)
Chrome plating on screws and dies intact.
Screw oil-cooling unit functioning.

4. Downstream:
* Water chiller functioning.
* Water spray nozzles: clogged?
* Vacuum or plug sizing tanks okay?
* Sizing plugs worn?
* Caterpillar puller slipping. Oil-contaminated?
* Saw blades sharp.

C: Accurate Production Records:

As discussed earlier, the concept of maintaining a “Materials Balance” reporting system offers an excellent way to monitor overall plant production efficiency, as well as the performance of each extrusion line. Typically, such records are compiled monthly and include the following:

1. Total pounds of incoming raw materials (by type) and total costs of these materials (whether paid yet or not.)
2. Total pounds of regrind made from scrap.
3. Total pounds of ‘on-spec’ product extruded (by extruder and by type).
4. Total pounds of unusable scrap (what percent of extrusion?)
5. Total pounds of product sold and shipped (by type) and sales value of shipments (whether paid or not)

Knowing fixed costs, this system’s variable cost input, along with other (i.e., hourly labor) variable costs should give the general manager a good picture of the monthly viability of the extrusion plant.

D: “Pound-Volume Pricing “ of PVC Compounds:

As stated earlier, PVC extruded products often are sold by volume (or length X cross-sectional area), while incoming raw materials are purchased by weight. Thus, it is imperative to a profitable plant operation that the costs of extruded products are known on a volume basis. This is accomplished by converting the pounds of each formulation ingredient and total formulation pounds, into cubic feet units, using specific gravity and density values for each ingredient. Such an exercise is described in detail below.

The starting point is water, having a specific gravity of 1.00 and a density of 62.4 pounds per cubic foot. Thus, each formulation ingredient, using its reported specific gravity, times the 62.4 lbs/cubic feet of water, can be converted to a pounds/cubic foot density value.

For rigid PVC extrusion, some typical formulation ingredients, their specific gravity and density would be:
<table>
<thead>
<tr>
<th></th>
<th>Specific Gravity</th>
<th>Density, lbs/cu.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference - water</td>
<td>1.0</td>
<td>62.4</td>
</tr>
<tr>
<td>PVC Resin</td>
<td>1.4</td>
<td>87.4</td>
</tr>
<tr>
<td>Acrylic process aid</td>
<td>1.18</td>
<td>73.6</td>
</tr>
<tr>
<td>Acrylic impact modifier</td>
<td>1.20</td>
<td>74.9</td>
</tr>
<tr>
<td>TiO2</td>
<td>4.20</td>
<td>262.1</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>2.71</td>
<td>169.1</td>
</tr>
<tr>
<td>Calcium Stearate</td>
<td>1.03</td>
<td>64.3</td>
</tr>
<tr>
<td>Paraffin wax, 165 degree M.P.</td>
<td>0.92</td>
<td>57.4</td>
</tr>
<tr>
<td>Oxidized polyethylene wax</td>
<td>0.93</td>
<td>58.0</td>
</tr>
<tr>
<td>Organotin stabilizer</td>
<td>1.02 - 1.17</td>
<td>63.6 - 73.0</td>
</tr>
</tbody>
</table>

To further illustrate, the ‘pound-volume’ calculations for three typical extrusion formulations would be:

**Type I PVC pipe**

<table>
<thead>
<tr>
<th></th>
<th>Lbs/cu.ft.</th>
<th>Cubic Feet</th>
<th>Cost/Lb</th>
<th>Total $</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC resin (K-65)</td>
<td>100.00</td>
<td>87.4</td>
<td>0.30</td>
<td>30.00</td>
</tr>
<tr>
<td>TiO2</td>
<td>1.00</td>
<td>262.1</td>
<td>0.10</td>
<td>0.50</td>
</tr>
<tr>
<td>Calcium Carbonate(1-2micron)</td>
<td>5.00</td>
<td>169.1</td>
<td>0.10</td>
<td>0.50</td>
</tr>
<tr>
<td>Calcium Stearate</td>
<td>0.60</td>
<td>64.3</td>
<td>0.54</td>
<td>0.324</td>
</tr>
<tr>
<td>165 Paraffin wax</td>
<td>1.20</td>
<td>57.4</td>
<td>0.45</td>
<td>0.54</td>
</tr>
<tr>
<td>Oxidized polyethylene wax</td>
<td>0.15</td>
<td>58.0</td>
<td>0.95</td>
<td>0.143</td>
</tr>
<tr>
<td>Organotin (pipe) stabilizer</td>
<td>0.40</td>
<td>63.6</td>
<td>1.80</td>
<td>0.72</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>108.35 lbs</td>
<td>1.2167</td>
<td></td>
<td><strong>$33.23</strong></td>
</tr>
</tbody>
</table>
Compound density = 90.1403 lbs/cu.ft.
Compound specific gravity = 1.4445
$ cost/pound = $0.3780/lb. ($0.38)
$ cost/cu.ft. = $34.073/cu.ft.

<table>
<thead>
<tr>
<th>PVC Capstock</th>
<th>Phr(lbs)</th>
<th>Lbs/cu.ft.</th>
<th>Density</th>
<th>Feet</th>
<th>$ /Lb</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC resin (K-65)</td>
<td>100.00</td>
<td>87.4</td>
<td>1.144</td>
<td>0.30</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Acrylic Process Aid</td>
<td>1.50</td>
<td>73.6</td>
<td>0.020</td>
<td>1.10</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Impact Modifier</td>
<td>5.00</td>
<td>74.9</td>
<td>0.066</td>
<td>1.45</td>
<td>7.25</td>
<td></td>
</tr>
<tr>
<td>Ti02</td>
<td>10.00</td>
<td>262.1</td>
<td>0.038</td>
<td>1.00</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>2.00</td>
<td>169.1</td>
<td>0.011</td>
<td>0.100</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Calcium Stearate</td>
<td>1.20</td>
<td>64.3</td>
<td>0.018</td>
<td>0.54</td>
<td>0.648</td>
<td></td>
</tr>
<tr>
<td>165 Paraffin wax</td>
<td>1.20</td>
<td>57.4</td>
<td>0.020</td>
<td>0.45</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Oxidized PE wax</td>
<td>0.15</td>
<td>58.0</td>
<td>0.002</td>
<td>0.95</td>
<td>0.143</td>
<td></td>
</tr>
<tr>
<td>Organotin stabilizer</td>
<td>1.25</td>
<td>73.0</td>
<td>0.017</td>
<td>3.00</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>122.30</td>
<td></td>
<td>1.3407</td>
<td></td>
<td>$54.08</td>
<td></td>
</tr>
</tbody>
</table>

Compound Density = 91.2210 Lbs/Cu.ft.
Compound Specific Gravity = 1.4619
Cost - $/LB = $0.4422 ($0.43)
Cost - $/Cu.ft. = $40.34/Cu.ft.

E. PLANT SAFETY: OSHA AND EPA COMPLIANCE

A workplace atmosphere that is safe, healthy, and congenial contributes to worker morale, job satisfaction, and thus helps insure an efficient, profitable production operation. This would be true even without the mandated regulations of OSHA. Today’s regulatory climate mandates a host of in-plant safety regulations. This often requires that an individual or committee be appointed to oversee and insure compliance with all applicable safety and health regulations.

Likewise, EPA requires strict control and monitoring of all air-borne, water-borne and solid effluent arising from any industrial manufacturing operation. Concerns in PVC extrusion can include emissions of powder (PVC, compound) to the air, fumes, waste water contamination and disposal of solid non-usable scrap. Again, an appointed individual or committee assumes responsibility for compliance.
X. REGULATORY - CODE AGENCIES

Depending on the PVC extruded product, the plant may need to deal with one or more of the regulatory or code agencies which exist to insure that industry or government standards are met for products used within their particular sphere of influence:

A. National Sanitation Foundation (NSF), Ann Arbor, Michigan
   Extraction, taste and odor testing of potable water in contact with PVC pipe and fittings.
   Formulations need N.S.F. approval, and in-plant inspections can occur.

B. Plastic Pipe Institute (PPI), Division of S.P.I., N.Y. City, N.Y.
   Hydrostatic Design Stress Committee oversees and approves pipe compounds for long term use with pressurized water systems.
   Pressure testing: 10,000Hr. data must extrapolate to 100,000Hrs. satisfactorily.

C. Underwriters Laboratory (U.L.), Chicago, Illinois
   Tests and approves PVC conduit for wire, cable and fiber-optic use.

D. U.S. Food and Drug Administration (USFDA), Washington, D.C.
   Regulates both direct and indirect food contact uses of PVC products.

All sanctioned formulation components must be listed in the appropriate section of the Code of Federal Register.

XI. PLANT OPERATION - ECONOMICS AND PROFITABILITY

Norman Perry’s chapter discussing plant operations in the first edition of this Encyclopedia (1977) cited a small single screw extrusion plant (4 lines) as the example to show costs and profitability. This discussion utilizes the same approach, but uses the current costs (2001) of building, equipment, and labor to staff our illustrative PVC extrusion plant.

A. Plant Staffing: One scenario we will use to staff our PVC extrusion plant and attendant costs:

<table>
<thead>
<tr>
<th>Position</th>
<th>Hourly Wage</th>
<th>Salary/yr.</th>
<th># people</th>
<th>Total $K/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gen. Mgr.</td>
<td>80K</td>
<td>1</td>
<td></td>
<td>80K</td>
</tr>
<tr>
<td>Purch./ Office Mgr.</td>
<td>45K</td>
<td>1</td>
<td></td>
<td>45K</td>
</tr>
<tr>
<td>Sect./Bk Keeping</td>
<td>12.00</td>
<td>25</td>
<td>3</td>
<td>75K</td>
</tr>
<tr>
<td><strong>Total Office (fixed cost)</strong></td>
<td><strong>$200K</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 1: LABOR COSTS
Quality Control:
- Q.C./Develop. Mgr. 55K 1 (fixed) 55K
- Lab Technicians 12.00 25 3 (var.) 75K
  (1 per shift)

Total Lab $130K

Blending/Mixing:
- Lead Blender 16.50 35K 1 (var.) 35K
- Blender Operators 12.00 25 3 (var.) 75K
  (1 per shift)

Total Blend Area $110K

Production:
- Production Mgr. 65K 1 (fixed) 65K
- Shift Foreman 19.00 40 3 (var.) 120K
- Extrusion Operators 16.50 35 6 (var.) 210K
- Production Helpers 12.00 25 12 (var.) 300K
  (1, 2 & 4 per shift, respectively)

Total production $695K

<table>
<thead>
<tr>
<th>Number of People</th>
<th>Total Wage/Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Total Staff 35</td>
<td>$1,135K</td>
</tr>
<tr>
<td>Fixed Cost Salaries 7</td>
<td>320K</td>
</tr>
<tr>
<td>Variable Cost Wages 28</td>
<td>815K</td>
</tr>
</tbody>
</table>

Adjustment to salaries and wages will include:
- Adding 30% to all wages for taxes, Social Security, Insurance.
- Adding an additional 3.0% for overtime, 5.0% for cost of shift differentials to all variable labor costs, or another 8.0%.
- Thus: $320K X 1.30 = $416K in Fixed Costs (office/supervisory)
- 815K X 1.38 = $1,124.7K in variable costs (3 shifts, labor)
- Total wages per year = $1,540.7K/year
- Plus, assume selling costs (salary+travel) of $1000K per year, or 3.0- 3.5% of sales.

B. Building, Utilities, Maintenance Costs:
- The plant of 100,000 square feet will carry a $6.50/sq. ft. cost per year to operate… $650,000/yr.
- We assume these other costs:
  - Utilities: Power and Water @ $250,000/yr.
  - Maintenance, Repairs @$250,000/yr.
C. Production and Laboratory Equipment - Annual costs
   (See sections VIII- B-8, and IX-A)
Annualized costs for plant and lab equipment are as follows, using a 10 year amortization schedule:
For Pipe - $3,925,000 and Lab...
   $ 136,500 totaling $4,061,500 @ 10 yrs = $406,150/yr.
For Siding & Profile - $6,990,000 and Lab...
   $136,500 totaling $7,126,500 @ 10 yrs = $712,650/yr.

D. Annual Operating Costs & Compound Conversion Costs:
The above information, coupled with yearly production based on our ‘full’ 7,600 hour year, or 80% year of 6,080 hours, will give total operating costs (overhead) and compound conversion costs per pound. These are determined as follows:

**TABLE II: PLANT OPERATING COSTS AND COMPOUND CONVERSION COSTS:**

<table>
<thead>
<tr>
<th></th>
<th>Pipe Plant/yr.</th>
<th>Siding/Profile Plant/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor - 3 shifts (hourly)</td>
<td>1,124,700</td>
<td>1,124,700</td>
</tr>
<tr>
<td>Management, Supervisory, Office</td>
<td>416,000</td>
<td>416,000</td>
</tr>
<tr>
<td>Sales Costs</td>
<td>1,000,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Building ($6.50/sq.ft./yr.)</td>
<td>650,000</td>
<td>650,000</td>
</tr>
<tr>
<td>Utilities (power &amp; water)</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Production &amp; Lab Equipment/year</td>
<td>406,150</td>
<td>712,650</td>
</tr>
<tr>
<td><strong>Annual Operating Costs</strong></td>
<td><strong>$4,126,550/ yr.</strong></td>
<td><strong>$4,433,050/yr.</strong></td>
</tr>
</tbody>
</table>

7600 hour/year - cost  $  542.97/hr.   $  583.30/hr.
6080 hr./yr. (80% usage)  678.71/hr.       729.12/hr.

Standard Extrusion Output Rates (See VIII - B-4):
2 CM92HP’s @ 1800/hr. = 3,600 lbs.
3 CM80HP’s @ 1000/hr. = 3,000 lbs.
3 CM55HP’s @ 500/hr = 1,500 lbs.
Plant Standard Rate:  8100 lbs/hr.
   At 7600 hr/yr.  61.6 MM lbs.
   At 6080 hrs (80%)/yr.  49.3 MM lbs.

Conversion Cost/ LB. of Compound
At standard output, and 80% year  $0.0837 /LB.   $0.0899/LB.
E. Material or Compound Costs:

As discussed in Section IX - D, “Pound Volume” pricing, our pipe plant will use a compound having a $0.31/ lb. cost, while our siding/profile plant will use $0.38/lb. substrate and $0.43/ lb. capstock compounds, at an 85%-15% respective use rate. Thus, for profile, the average compound cost becomes $0.3875/lb.

From a “material-balance” viewpoint, we will assume both types of plants operate at an overall 8% scrap rate, and 4% of that material is used as regrind in saleable products, leaving 4% as unusable, or unaccounted lost material. Thus, we will assume that 96% of our incoming raw material is converted to saleable product. The “base” compound costs must then be converted to an “extended” compound cost (due to the 4% loss) as follows:

<table>
<thead>
<tr>
<th></th>
<th>Base Cost/lb.</th>
<th>Extended Cost/lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>$0.3100/Lb. /0.96 = $0.3229/Lb.</td>
<td></td>
</tr>
<tr>
<td>Siding Profile (Average cost)</td>
<td>0.3875/Lb/ 0.96 = 0.4036/Lb.</td>
<td></td>
</tr>
</tbody>
</table>

F. Total Sales Revenue:

Based upon our assumed total production year of 49,300,000 Lbs. (at 80% plant usage), and a $0.46/Lb. average selling price for pipe, or a $0.60/ Lb. selling price for siding/profile, we see the following total sales revenues potentially available:

Pipe: 49,300,000 Lbs @ $0.46/Lb = Total Sales of $22,678,000.
Siding/profile: 49,300,000 Lbs @ $0.60/Lb = “ “ 29,580,000.

A word of caution regarding sales revenue must be inserted at this point. Using pipe as an example, maximizing plant productivity does reduce unit costs, theoretically enhancing profit margins. However, this is only true if all production can be sold at the desired price to achieve the improved profit. In other words, a demand-- or market-- must exist that will absorb this increased productivity. Otherwise, simply pushing more product out the door, to inventory, will create a glut. This situation is then addressed by more vigorous sales and marketing efforts, often with depressed pricing. Unfortunately, this condition periodically develops in the PVC pipe industry, with selling prices depressed to $0.11/lb. over base resin cost. Thus, a $0.30/lb. PVC resin price may only translate to a $0.41/lb. pipe selling price. However, our example PVC pipe plant will use a $0.16/lb. differential, or $0.46/lb. selling price, for analyses of plant profitability that follow.

Why does this situation occur? One reason may be that some of the larger PVC resin producers also own their own pipe extrusion facilities. Large reactor PVC resin production is difficult to turn off and on with short term ups and downs of the resin market. Thus, during “slow” seasons (i.e. winter months), large numbers of “horizontal silos” (read: railcars) of PVC resin wind up at their respective pipe plants. Production of pipe-to
inventory continues through the slack winter buying season. With the coming of spring, the market then sees reduced pricing until excess pipe inventory is moved out and sold.

The investor or owner needs to recognize that not only high productivity, but reasonably profitable sales of that product are necessary to the successful business. Excess production dumped on a market will cause the downward pricing spiral, as competitors do not willingly give up their share of that market. New markets must be created (i.e. fencing and docking) in order to enjoy profitable growth. With the above cautions in mind, we now examine the profit potential of our PVC extrusion plant.

G. Plant Profit Potential:

Gathering all of the cost data together, we can now determine the gross profit potential for our PVC extrusion plants.

<table>
<thead>
<tr>
<th></th>
<th>Pipe</th>
<th>Siding/profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>‘Real-world’/ Desired</td>
<td></td>
</tr>
<tr>
<td><strong>Average Selling Price/Lb.</strong></td>
<td>0.4100/lb 0.4600/lb</td>
<td>0.6000</td>
</tr>
<tr>
<td><strong>Base Compound Cost/Lb.</strong></td>
<td>0.3100/lb.</td>
<td>0.3875</td>
</tr>
<tr>
<td><strong>Extended Compound Cost/Lb. @4%loss</strong></td>
<td>0.3229/lb.</td>
<td>0.4036</td>
</tr>
<tr>
<td><strong>Conversion Cost/Lb.</strong></td>
<td>0.0837/lb.</td>
<td>0.0899</td>
</tr>
<tr>
<td><strong>Potential Profit/Lb.</strong></td>
<td>0.0034/lb.</td>
<td>0.0534/lb.</td>
</tr>
<tr>
<td><strong>Annual Production, Lbs. (80% std.rate)</strong></td>
<td>49,300,000</td>
<td>49,300,000</td>
</tr>
<tr>
<td><strong>Profit Potential yearly</strong></td>
<td>$167,620</td>
<td>$2,632,620</td>
</tr>
<tr>
<td><strong>Percent of Profit on Sales.....</strong></td>
<td>0.83%</td>
<td>11.6%</td>
</tr>
</tbody>
</table>

H. EFFECTS OF INCREASED PRODUCTIVITY ON PROFIT:

The importance of continuing efforts to increase sales and production efficiency can be seen in the tables IV and V below. An overall average 10% increase in extrusion output rate will result in an even larger profit increase, using the same hour’s per year basis.

<table>
<thead>
<tr>
<th></th>
<th>Pipe</th>
<th>Siding/profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Extrusion Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---8 lines---</td>
<td>8100 lbs/hr.</td>
<td>8100 lbs/hr.</td>
</tr>
<tr>
<td>10% output increase</td>
<td>810 lbs/hr</td>
<td>810 lbs/hr.</td>
</tr>
<tr>
<td>Improved extrusion rate</td>
<td>8910 lbs/hr.</td>
<td>8910 lbs/hr.</td>
</tr>
<tr>
<td>Annual Production @80% use rate (6080 hrs)</td>
<td>54,172,800 lbs.</td>
<td>54,172,800 lbs.</td>
</tr>
</tbody>
</table>
New Conversion Cost/lb. $0.0762 /lb. $0.0818 /lb.
Extended Compound Cost/lb. $0.3229 /lb. $0.4036 /lb.
Average Selling Price/lb. $0.4600 /lb. $0.6000 /lb.
Potential Profit/lb @ 10% inc. $0.0609 /lb. $0.1146 /lb.
Annual Profit @ 10% inc. $3,299,124/yr. $6,208,203
Profit percent increase +25.3% +18.24%
(over Table III)
New sales revenue $ 24,919,488/yr. $ 32,503,680/yr.
New profit margin (10% output incr.) 13.24% 19.1%

Further, if the plant’s equipment use can be increased to a 90% rate from 80% (6840 hours), by reducing “downtime”, an even greater leverage effect upon profit can be realized (See Table V).

**TABLE V: Effect on Profit by Increasing Equipment Use to 90%**

<table>
<thead>
<tr>
<th></th>
<th>Pipe</th>
<th>Siding/Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Standard Extrusion Rate</td>
<td>8910 lbs/hr.</td>
<td>8910 lbs/hr.</td>
</tr>
<tr>
<td>(8 Lines)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Production @90% (6840 hrs.)</td>
<td>60,944,400 lbs.</td>
<td>60,944,400 lbs.</td>
</tr>
<tr>
<td>ConversionCost @ 90% Use</td>
<td>$0.0677/lb.</td>
<td>$0.0727/lb.</td>
</tr>
<tr>
<td>Extended Compound Cost</td>
<td>$0.3229/lb.</td>
<td>$0.4036/lb.</td>
</tr>
<tr>
<td>Average Selling Price</td>
<td>$0.4600/lb.</td>
<td>$0.6000/lb.</td>
</tr>
<tr>
<td>Potential Profit @ 90% Use</td>
<td>$0.0694/lb.</td>
<td>$0.1237/lb.</td>
</tr>
<tr>
<td>Annual Profit @ 90% Use</td>
<td>$4,229,541/yr.</td>
<td>$7,538,822/yr.</td>
</tr>
<tr>
<td>% Profit Increase(90% use over 80% use-Table IV)</td>
<td>+28.2%</td>
<td>+21.4%</td>
</tr>
<tr>
<td>New Sales Revenue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10% output increase +90% use)</td>
<td>$28,034,424</td>
<td>$36,566,640</td>
</tr>
<tr>
<td>New Profit Margin</td>
<td>15.1%</td>
<td>20.6%</td>
</tr>
</tbody>
</table>

In summary, by boosting output rates 10% and utilizing 90% of equipment hours, our example extrusion plant’s profit margins improve thus:

- Pipe: 11.60%---->13.24%---->15.1%
- Siding/Profile: 17.75%---->19.10%---->20.6%

Once again, although specific numbers will differ, all PVC processing operations will have to deal in some way with the factors affecting profitability similar to those discussed above.
XII. CONCLUSION: MANAGEMENT’S ROLE:

With site selection, plant construction, equipment purchase and staffing complete, the most important attribute to a successful, profitable venture yet needs discussion.

The entrepreneur, owner, and general manager must SET THE TONE for our PVC production operation. How will the company be perceived by its employees, by its customers and by its neighbors in the community?

Apart from a clean, safe workplace with pleasant employee lunch and locker/shower facilities, it is management’s basic philosophy in motivating, leading and managing their work force that will affect “esprit d’corps” and morale most of all. An atmosphere that invites and respects workers’ idea inputs, offers incentives for goals achieved, and generally inspires overall “good vibes” among all, is an atmosphere that will spawn much higher productivity and quality than its antithesis. Employees having pride in their work and a feeling of individual contribution to overall performance will help ensure a happy customer base, as well as help foster a positive company image in the community.

For the above scenario to occur, it must start at the top!

XIII. REFERENCES

(2)- Jim Ballard, General Manager, NAPCO, Inc. Mt. Vernon, Ind. Personal Communication.
(4)- Richard Tinurelli, Director of Sales, Extrusion Systems, Cincinnati Milacron, Inc., Cincinnati, OH., Personal Communication.