3L Filters Ltd. Adopts DCA Technology to Improve Position in the Automotive Sector

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Abstract

The automotive industry invests heavily in filtration pressure vessels to cleanse fluids used in manufacturing. The market for these standard engineered products is highly competitive. As a vessel manufacturer, 3L Filters Ltd.'s revenue is distributed evenly between standard engineered products and custom engineered products. The company was determined to improve its competitiveness through cost reduction and shortened manufacturing cycles. 3L Filters researched technologies for improving accuracy and efficiency in engineering. The company selected a design and costing automation (DCA) system capable of compressing quotation and engineering-to-manufacturing lead-time by 90%. Consequently, more engineering resources were available for custom engineered products. The implementation of DCA demanded significant time and effort, but was found to provide the expected benefits and more. This paper describes how the project has enabled 3L Filters Ltd. to improve quality and customer response for standard products while simultaneously increasing attention to custom products.

INTRODUCTION

3L Filters Ltd. is an engineer-to-order company. Engineering represents a major component of cost in delivery of the company's products because every unit shipped is adapted to the customer's unique requirements. The company's executive management saw that competitive advantage hinged on improving efficiency while reducing the fixed cost of Engineering.

3L Filters undertook a major initiative to make fundamental changes to its business methods. The vision was to automate Engineering design and product costing as far as practical. This paper discusses the rationale, objectives, tactics, and outcomes of the project.

PROJECT RATIONALE

3L Filters Ltd. is a design / manufacturer of filtration components and systems for the industrial and nuclear markets. New Canadian nuclear construction has diminished to the point that the industrial market is playing a more predominant role in the company's success. In the past, the company has been more focused on the nuclear market and as such had developed certain traits that hinder competition in the industrial marketplace.

In the nuclear industry, for example, a custom engineering design approach is commonplace, accompanied by longer design-to-manufacturing turnaround times. Consequently the nuclear industry is subject to premium pricing. The industrial market is exactly the opposite. In order to

continue growing revenues, 3L Filters was faced with the challenge of modifying its practices to deal with the reality of today's marketplace. Standard high-quality products must be delivered quickly at the lowest possible cost.

A review of internal procedures led company management to recognize the need for change in three key areas:

- Engineering philosophy — How could the company improve pre-sales and production design activities to save time and effort?
- Price competitiveness — What contributors to product cost could be eliminated without impacting product quality?
- Market focus — Where should the company concentrate its efforts to maximize return on invested capital?

As a recognized supplier to the automotive industry, 3L Filters had a significant stake in market share to protect and grow. The answers to these questions were framed in the context of improving competitiveness in that sector.

PROJECT OBJECTIVES

Management set a strategic goal to increase standard product revenues by 20% over a period of two years. 3L Filters defined three practical objectives.

1) **Standardize products and processes**

Half the company's revenue was generated by standard products comprised of 13 product families. Each standard product shipped was designed to meet the unique performance specifications of industrial customers. Before undertaking the DCA implementation project, 3L Filters had informal processes in place for capturing product specifications and creating a physical design for the required product. Bills of Materials and production plans were individualized for each job to enable costing of a proposed product. Engineering philosophy was based on a custom design process that inherently tended to hinder the standardization process. The situation led to extraneous work and delay in responding to most customer requests for quotation. This impediment to productivity needed resolution.

2) **Improve company efficiency**

Standardization of products and processes was considered an essential step to achieving efficiency goals. In parallel with Objective 1) above, 3L Filters planned to improve its competitive advantage in four areas.

a) Engineering throughput

Manufacture of industrial filtration pressure vessels is a very mature market with dozens of North American competitors. Although engineering design is an essential component of value in standard product, its cost must be absorbed by the producer. 3L Filters set a goal of eliminating redundancy in Engineering work to reduce internal technical costs by at least 50%.

b) Quotation response time and effort

In its mature market 3L Filters was committed to winning as much business as possible. Responding to requests for quotation represented over 50% of the Engineering Department's activity. Leveraging improvements in engineering throughput would also enable the company to be far more responsive to RFQs. Since only 1 quotation in 10 yielded a purchase order, it was essential to deliver quotations quickly and efficiently without siphoning technical resources from production-related design work.

c) Cost competitiveness

3L Filters included Engineering work in production overhead. It was convenient to allocate inefficiencies in the technical function to product cost, but this practice reduced the company's competitiveness. To correct the problem, engineering overhead had to be reduced.

d) Manufacturing delivery lead time

The company was under constant pressure to improve manufacturing delivery lead time. In the 1990s, 8 to 10 weeks delivery was the industry norm. Today vessel manufacturers are expected to ship within 4 to 6 weeks of receipt of order. At 3L Filters, it was recognized that improvements in engineering throughput could make this new target achievable without increasing production costs.

3) **Earn return on investment within 12 months**

Manufacturers must engage in continuous improvement to maintain competitive advantage, but expenditures have to be justifiable. 3L Filters had past experiences with information technologies that did not deliver the returns promised. Management set conditions on project investment – payback must be short term, visible, and sustained.

DESIGN AUTOMATION ACTIVITY

3L Filters Ltd. had set clear goals for a project to enhance efficiency and competitiveness. Now several departments were dedicated to pursuing the mandate. The technical knowledge processes of the company were to be revamped. This involved the functions of Sales, Applications Engineering, Purchasing, Estimating, and Production Engineering. Because lack of design standardization and engineering capacity limits were key obstacles to success, the Engineering Manager assumed the role of primary champion. The Sales Manager also had a major stake in the outcome and was instrumental in guiding the process.

In the past, the company had tried to standardize design procedures and production drawing formats. However, the infinite variety of unique designs even within the context of a standard product family made the task intractable. Paper documentation could not be organized with clarity and accessibility to eliminate confusion. 3L Filters was using 2D CAD for quotation and production design purposes, but it represented only marginal advantage over paper-based approaches. Therefore, the company sought an enterprise information technology approach.

The software industry was surveyed to find a proven approach to formalizing design standards and procedures. The new concept of design and costing automation (DCA) was reviewed, and

3L Filters selected an experienced engineering software firm to demonstrate its capabilities in delivering a working solution. Before committing to a full DCA implementation, 3L Filters contracted a pilot project to automate the design of one of its 13 product families. Within one month, the selected vendor demonstrated its grasp of the problem and delivered a working prototype of a robust DCA environment. This proof-of-concept instilled the company with the confidence to proceed with the entire project.

A DCA environment is a computerized platform which encapsulates both the geometric and non-geometric description of a company's assembled products. Configuring DCA with engineering rules and standardized components and fabrication processes is a specialized task. 3L Filters staff did not have the experience or free time to dedicate to the activity, so the company contracted the DCA vendor to build the company's product knowledge models. The work involved automating the design and costing of 13 distinct product families of filtration pressure vessels used to remove all imaginable impurities from all varieties of industrial fluids.

1) **Detailed Design**

Modern DCA technology relies on construction of a 3-dimensional digital prototype of the desired product. Robust parametric solids assembly CAD is harnessed to realize the meticulous detail inherent in a complex manufactured product. 3L Filters provided their DCA vendor with detailed component drawings and assembly layouts to guide the process of modeling the intricate details of a finished product. Every variable dimension of every component was considered in the context of assembly relationships, and hundreds of 3D CAD models were created to represent the real-life elements of 3L Filters' vessels. The process incorporated the engineering rules behind selection of specific components and materials.

3L Filters designs and delivers sophisticated product that complies with the American Society of Mechanical Engineering (ASME) Pressure Vessel Code. Therefore, the DCA platform was adapted to reflect industry-specific design rules necessary to meet the specification. For example, no vessel pressure hull openings could be within 2 inches of the nearest weld bead. Temperature and pressure limits for various pressurized materials were tabled. Dozens more critical design constraints were incorporated. All of these conditions were programmed into the DCA platform. In parallel with this configuration process, a user interface was customized to allow non-technical personnel to describe any filtration pressure vessel and generate its detailed production-ready design without violating pre-programmed Engineering guidelines.

2) **Bill of Materials**

Geometric design was only one key element of the DCA system implementation. It was also critical to extract an accurate purchasing Bill of Materials for any generated design. Precise determination of delivered cost of any standard product was necessary to fully reduce engineering involvement in quotations. 3L Filters products operate at high temperature and pressure with corrosive fluids. Stainless steel and high-alloy materials are commonly used in their fabrication, so every pound of material must be accounted for in a design, particularly in formulating a competitive Sales quotation that would win a purchase order. The DCA vendor worked closely with the Purchasing Department to assign internal part numbers to geometric components in the detailed design.

3) **Fabrication planning**

Costing a filtration pressure vessel at the quotation stage involves more than purchased materials. 3L Filters standard products incorporate many hours of ASME-certified welding. Top wages are paid for shop floor personnel with code-compliant credentials. The DCA platform was programmed to account for this cost by representing vessel weldments with automatic computation of bead size and inches of travel. Other major contributors to assembly hours were also considered, including plate rolling time and surface finishing.

4) **Costing**

The DCA platform was eventually configured with a detailed understanding of a 3L Filters standard product design, materials content, and manufacturability. With each automatically-generated product design, all of the above contributors to product cost were amalgamated into a format compatible with 3L Filters' current enterprise resource planning (ERP) system. An electronic document was submitted to the ERP system for roll-up calculation of total purchasing and processing cost, referencing the company's internal cost standards. This final step in DCA implementation was necessary to price a standard product for delivery quickly and reproducibly without relying on engineering input.

DCA SYSTEM PROFILE

Within three months of contracting the DCA vendor to build the 3L Filters unique design and costing automation environment, the company was testing its first product family, the FW Micronic particulate filtration system. There was still considerable work left to finish the remaining 12 product families, but 3L Filters quickly became familiar with the capabilities of the system. The DCA platform is based on current software technology components and philosophy. Key characteristics include:

1) **Custom interface for product specification input**

The Sales Department worked with the Engineering Department to advise the DCA vendor on configuring a user-friendly interface for collecting product specifications. The result was a multi-screen input process that ensured all relevant parameters were gathered prior to generation of a detailed product design. The interface was refined several times until 3L Filters staff were comfortable using it in daily activity.

2) **Web-based integration with existing PC networks**

DCA technology addressed several issues important to 3L Filters. The software environment integrated easily and transparently with the company's existing computing infrastructure. The system is web-based and operates through Internet browsers on every workstation in the Cambridge facility. Packaged on a single webserver, the DCA platform was literally "dropped into' 3L Filters information technology environment with Ethernet networking and an IP address for accessing its functions.

3) **Enterprise server with all DCA applications centralized**

The selected DCA platform eliminated the need to install any application software on a mix of workstations. This was a significant advantage because the alternative would have

been to conduct a whole scale hardware/software upgrade before implementing the technology. DCA is a sophisticated mix of vendor-proprietary software orchestrating the functions of commercial software components including 3D solids CAD, a relational database, and various translators required to deliver technical documentation for universal readability.

4) **Generates detailed 3D CAD assemblies of product designs**

3L Filters selected its DCA platform on the basis of overall versatility. The NeXtreme Automation DCA environment operates on the principle of creating a full-scale geometric prototype of the company's configured standard product. This automatically-generated 3D CAD assembly is available on demand to the Engineering department.

5) **Transfers detailed product attribute data to ERP for costing**

The final link to product costing is through a custom-formatted electronic document generated in conjunction with the detailed geometric design. 3L Filters depends on its ERP system to manage standard costs, track labor, and provide financial oversight on daily operations. The DCA vendor worked with the ERP vendor to tailor the link between the two systems for transferring Bills of Material and basic Manufacturing Routings generated with each Sales quotation. The transaction is invoked through a batch process.

DCA APPLICATIONS

The DCA system features outlined above support 3L Filters daily activities in several key areas.

1) **Sales Quotations**

a) <u>Rapid product configuration</u>

Every 3L Filters sales representative is an authorized user of the DCA system. Requests for quotation are addressed quickly whether received by email, fax, or even during a telephone conversation. The salesperson logs into the system, selects a standard product family, then begins the process of generating a quotation. The data input sequence is tailored to ensure that all necessary data is gathered, and where information is missing, the user is prompted to fill in the gaps (Figs. 1-4).

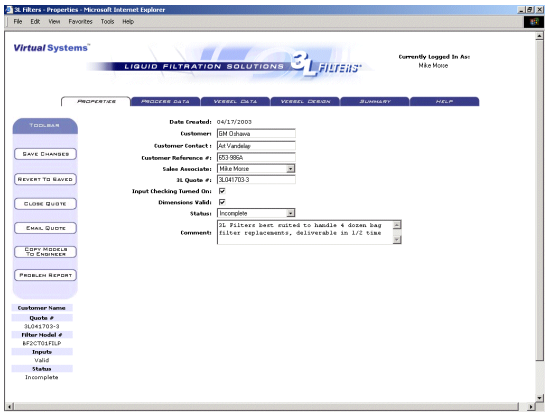


Fig. 1 - Quotation Profile Input

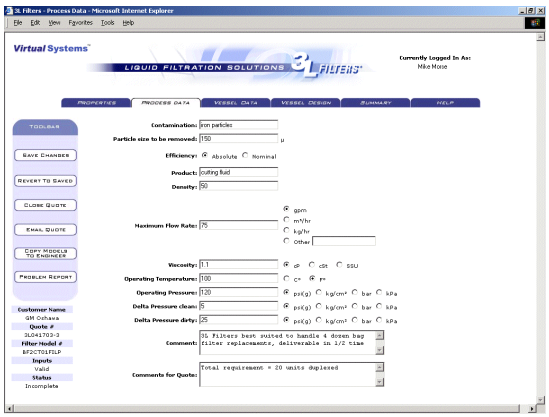


Fig. 2 - Process Specifications Input

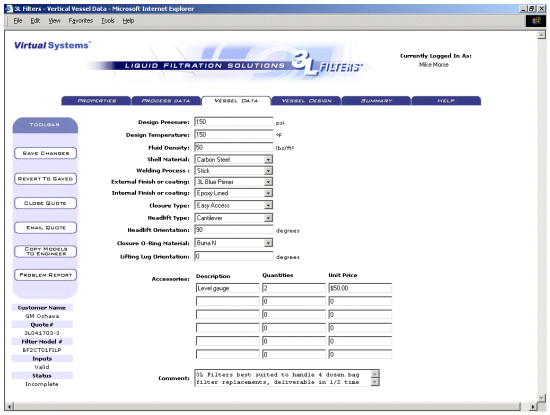


Fig. 3 - Design Specifications Input

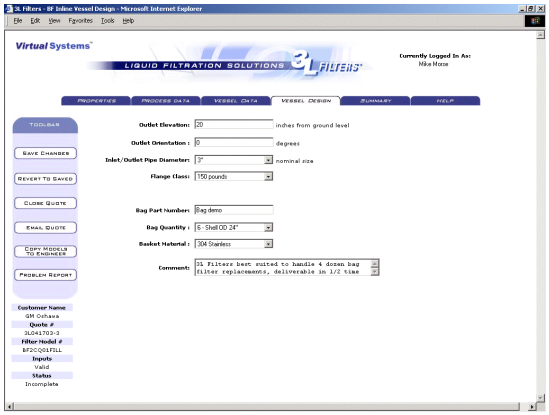


Fig. 4 - Installation Constraints Input

b) <u>Design visualization and approval documents</u>

At the end of the input process, a design viability check is performed automatically to ensure that the requested product configuration is deliverable (Fig. 5). At that point, the DCA system invokes the CAD prototype generator. Technical documentation is produced for review in less than 10 minutes, ready for emailing to the customer.

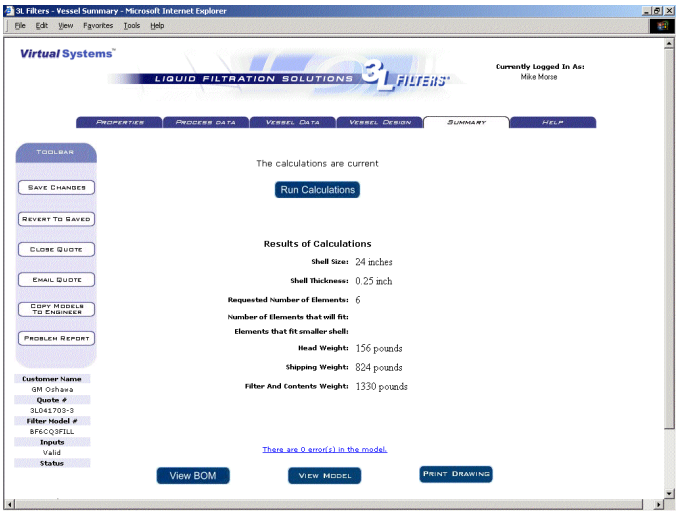


Fig. 5 - Design Viability Review & Results

Two visualization aids are used by Sales to confirm that the product specifications have generated a viable design. An approval drawing is output in universally-readable Adobe PDF format (Fig. 6). It reflects key size and installation dimensions. The second 'document' is a compact self-extracting graphics file which explodes into an exact replica of the 3D CAD assembly, viewable by any Internet browser (Fig. 7). This model reveals no dimensional detail, protecting 3L Filters from design piracy if viewed by the competition.

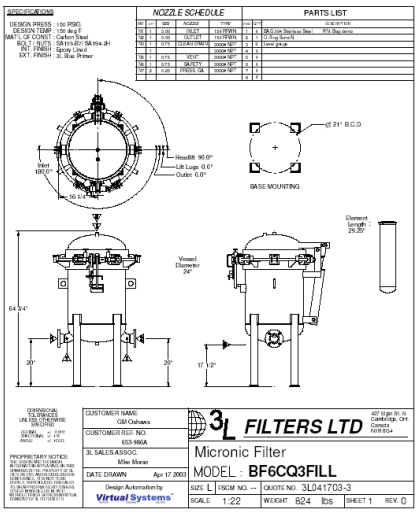


Fig. 6 - PDF-format Approval Drawing

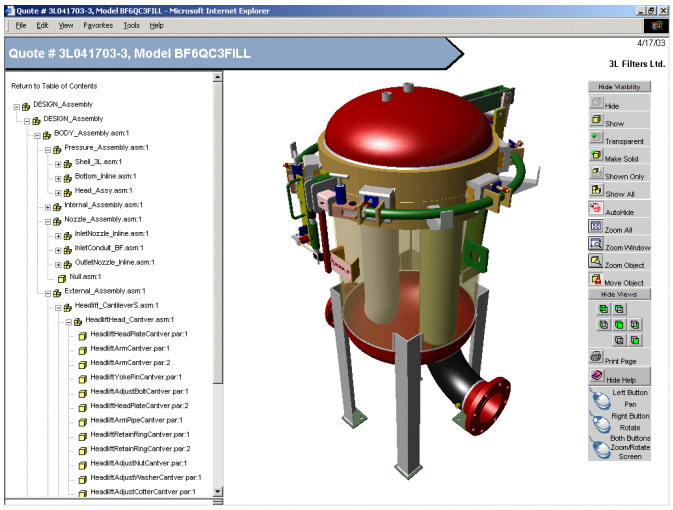
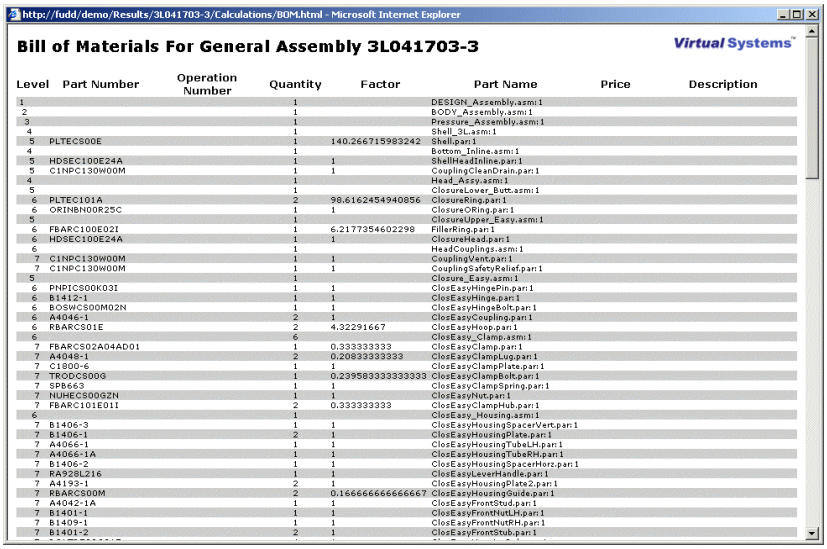


Fig. 7 - 3D Browser-viewable Model

2) Purchasing

The DCA system produces a detailed Bill of Materials and basic Manufacturing Routing automatically (Fig. 8). The Sales Department submits the electronic document to 3L Filters' ERP system for cost rollup. If a purchase order is received against any quotation, the Purchasing Department can place orders immediately for materials and components with confidence. All quoted configurations are maintained permanently in the DCA system for retrieval and optimization to meet changing customer price/performance requirements.



Level	Part Number	Operation Number	Quantity	Factor	Part Name	Price	Description
1			1		DESIGN_Assembly.asm:1		
2			1		BODY_Assembly.asm:1		
3			1		Pressure_Assembly.asm:1		
4			1		Shell_3L.asm:1		
5	PLTECS00E		1	140.266715983242	Shell.par:1		
4			1		Bottom_Inline.asm:1		
5	HDSEC100E24A		1	1	ShellHeadInline.par:1		
5	C1NPC130W00M		1	1	CouplingCleanDrain.par:1		
4			1		Head_Assy.asm:1		
5			1		ClosureLower_Butt.asm:1		
6	PLTEC101A		2	98.6162454940856	ClosureRing.par:1		
6	ORINBN00R25C		1	1	ClosureORing.par:1		
5			1		ClosureUpper_Easy.asm:1		
6	FBARC100E02I		1	6.2177354602298	FillerRing.par:1		
6	HDSEC100E24A		1	1	ClosureHead.par:1		
6			1		HeadCouplings.asm:1		
7	C1NPC130W00M		1	1	CouplingVent.par:1		
7	C1NPC130W00M		1	1	CouplingSafetyRelief.par:1		
5			1		Closure_Easy.asm:1		
6	PNPICS00K03I		1	1	ClosEasyHingePin.par:1		
6	B1412-1		1	1	ClosEasyHinge.par:1		
6	BOSWCS00M02N		1	1	ClosEasyHingeBolt.par:1		
6	A4046-1		2	1	ClosEasyCoupling.par:1		
6	RBARCS01E		2	4.32291667	ClosEasyHoop.par:1		
6			2		ClosEasy_Clamp.asm:1		
7	FBARCS02A04AD01		1	0.333333333	ClosEasyClamp.par:1		
7	A4048-1		2	0.20833333333	ClosEasyClampLug.par:1		
7	C1800-6		1	1	ClosEasyClampPlate.par:1		
7	TRODCS00G		1	0.239583333333333	ClosEasyClampBolt.par:1		
7	SPB663		1	1	ClosEasyClampSpring.par:1		
7	NUHECS00GZN		1	1	ClosEasyNut.par:1		
7	FBARC101E01I		2	0.333333333	ClosEasyClampHub.par:1		
6			1		ClosEasy_Housing.asm:1		
7	B1406-3		1	1	ClosEasyHousingSpacerVert.par:1		
7	B1406-1		2	1	ClosEasyHousingPlate.par:1		
7	A4066-1		1	1	ClosEasyHousingTubeLH.par:1		
7	A4066-1A		1	1	ClosEasyHousingTubeRH.par:1		
7	B1406-2		1	1	ClosEasyHousingSpacerHorz.par:1		
7	RA928L216		1	1	ClosEasyLeverHandle.par:1		
7	A4193-1		2	1	ClosEasyHousingPlate2.par:1		
7	RBARCS00M		2	0.166666666666667	ClosEasyHousingGuide.par:1		
7	A4042-1A		1	1	ClosEasyFrontStud.par:1		
7	B1401-1		1	1	ClosEasyFrontNutLH.par:1		
7	B1409-1		1	1	ClosEasyFrontNutRH.par:1		
7	B1401-2		2	1	ClosEasyFrontStub.par:1		

Fig. 8 - Bill of Materials & Routing Output

3) Production Engineering

Most generated product designs are discarded after use in the Sales quotation process. However, when a purchase order is won, Production Engineering can retrieve the quoted detailed design (Fig. 9) and perform last-minute review and refinement before releasing

the customer's order to Manufacturing. Detailed shop prints are generated error-free by referencing the accurate 3D assembly model and components in associative drawings.

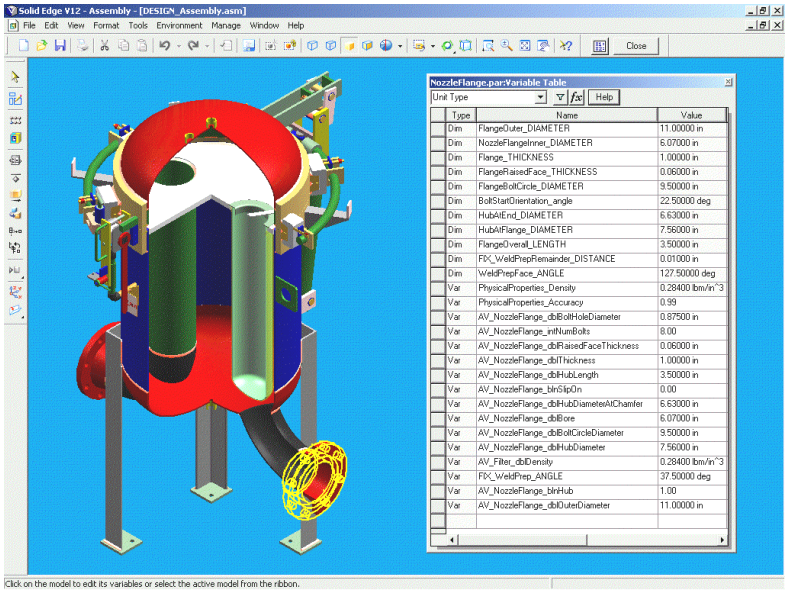


Fig. 9 - Sectioned 3D CAD Assembly with 1,000s of Design Variables

PROJECT OUTCOMES

3L Filters set out to standardize products and processes and increase company efficiency. Measured results for its standard products business over a 12-month period include:

- Quotation turnaround time was reduced from an average of 7 days to only 4 hours. This enabled the company to address many more RFQs than previously possible, even those considered marginal opportunities.
- The success 'hit-rate' of quotations converted to purchase orders doubled, increasing from 8% to 16%. The company credits the speed and accuracy of the new quoting process with this dramatic improvement. Sales prospects are surprised to receive responses to RFQs so quickly, and finding prices competitive, are more inclined to commit to a manufacturer that has automated its design function.
- Pre-Sales engineering work was virtually eliminated, reduced by 90% because the DCA-generated 3D design is verified and optimized by the Sales Department. The Engineering Department now has confidence in design 'decisions' made by the DCA system. Review of most 3D CAD designs occurs only after a purchase order is placed.
- Scheduling conflicts between the demands for standard and custom engineering activity were reduced by 40%. This outcome has allowed 3L Filters to concentrate on growing its more lucrative custom business without sacrificing opportunity and profitability in the standard products marketplace. Production design lead time has been reduced by 75%.

FUTURE WORK

3L Filters is taking full advantage of its current state of DCA operation, but further work is required to realize the system's full potential. The company is working on a continuing basis with the DCA vendor to plan and execute a number of initiatives.

1) **Improve the interface between DCA and ERP**

One issue that has not been resolved satisfactorily is the transparency of electronic communication between the DCA system and 3L Filters' existing ERP system. For the moment, a batch process must be invoked to deliver the DCA-generated Bill of Materials and Manufacturing Routing to ERP. A real-time process is envisioned. The main difficulty in achieving this goal is the ERP vendor's lack of enthusiasm in co-operating with the DCA vendor. The company is considering changing ERP platforms to ensure best integration.

2) **Introduce more flexibility for custom engineered product**

The current DCA system implementation does its prescribed job in automatically designing an infinite variety of designs for 13 distinct standard product families. The original project definition was focused on creating a Sales support tool, but now the Engineering Department would like support for interactive original design. Each quoting session is currently limited to design variations within a pre-selected product family. The next step will be to eliminate that restriction so an arbitrary filtration pressure vessel can be engineered in minutes to deliver unique performance characteristics.

3) **Generate more low-level manufacturing instructions automatically**

3L Filters does not currently define its manufacturing processes at a granular level. In other words, machine and labor requirements are generally related to a specific component's production. A cost factor is assigned to each high-level fabrication step, but individual machining or setup operations are not distinguished. The DCA system has the capacity to be configured with total detail in this regard. The company expects to begin mapping production processes to isolate important cost contributors as affected by design variations. This initiative will add further precision to the product costing process.

4) **Expose the DCA system to the Internet**

3L Filters has saturated its local geographic market for filtration pressure vessels. Further rapid business growth will be dependent on penetrating new foreign markets. The cost of opening Asian, European, and South American engineering facilities is prohibitive, so the company intends to engage manufacturer's agents in those regions. The DCA system will be launched as an Internet-accessible quoting system for use by designated distributors. No extra overhead will be required to address foreign markets until a quotation becomes a purchase order. 3L Filters will be confident of delivering its standard product at a profit because the company's Canadian-based knowledge engine is automatically designing and pricing units for sale. Another application for Internet-accessibility is to provide loyal customers with the ability to configure and price product directly in conjunction with their own internal design processes.

CONCLUSIONS

3L Filters has taken a visionary step in implementing design and costing automation (DCA) technology. The prime motivation was to improve the company's position in the automotive sector, but the benefits have unexpectedly provided competitive advantage in all its markets. Two important observations bear discussion.

1) **Primary project objectives were met**

a) Most products and processes are now standardized

3L Filters has made several attempts in the past to arrive at this goal, but never completed the job. The DCA implementation project was a resounding success in that the company's knowledge base is now captive in a robust automation platform. Proprietary technical knowledge, formerly held exclusively in the minds of key staff members, is accessible to any authorized employee. The company is no longer vulnerable to departure or retirement of experienced people. In addition, new hires can become productive in a fraction of the time traditionally required to teach them how to design and price filtration pressure vessels.

b) Company efficiency is significantly improved

Upon reaching the goal of design standardization, 3L Filters discovered that many hidden costs vaporized. By functional department;

Sales staff are able to handle more prospects and customers without losing track of the company's market opportunities. A complex product quotation can be retrieved and re-priced months later in the same few hours required for the first customer contact. Furthermore, any sales representative can deal effectively with any customer – response is not delayed by the absence of the usual account manager.

Engineering staff are not required to interface with Sales for most quotations. The DCA platform handles the vast majority of design and Bill of Materials generation functions automatically in a few minutes. This result has a two-pronged advantage. Engineers and designers are now far more focused on the premium-priced custom products (e.g. nuclear) without segmenting their valuable time intermittently between standard and custom design work. Design quality is up while overhead is down.

Purchasing staff have eliminated the time-consuming ritual of consulting the Engineering Department repeatedly on Bill of Materials details. Each quotation and/or purchase order is accompanied by an exact, calculated DCA system output which lists the part number, description, and quantity or factor of every raw material, component, fastener, and weldment used in construction of a standard product.

Manufacturing staff now shave hours off fabrication and assembly of standard products because the detailed design has been reproducibly automated and reviewed in full 3D prior to release to the shop floor. Raw material cutting and machining is precise and rarely subject to second-guessing Engineering's output. Waste levels in both labor and material are the lowest ever in the company's history.

In effect, the goal of standardizing products and processes has yielded unexpected new staff efficiencies in all 3L Filters departments. The most visible symptom of this improvement is a major reduction in paperwork transmitted between departments.

c) The project paid for itself in less than a year

The full DCA implementation took over a year to complete, but that was primarily due to the company's unfamiliarity with the process. Within 3 months of committing to the DCA vendor, 3L Filters was designing its highest volume standard product automatically. At that point, the time savings and customer-response advantages began to have a direct impact on operating costs. Before the final release of the DCA knowledge base was commissioned, the system had already generated a positive return on investment. It is estimated the system has accounted for the equivalent of 2 new Sales positions and 4 new Engineering positions without adding any new salaries to the company payroll.

2) **Impractical to implement with internal resources alone**

As previously noted, 3L Filters was unfamiliar with the exacting work of standardizing products and processes. It became clear why the company had been unsuccessful in previous attempts to change company technical practices. Outside help was essential for successful completion of the project. Why?

a) Resources are strained by daily activity

3L Filters wanted to change its internal practices but could never seem to free up staff time long enough to make headway on any focused project. The Engineering Department was always charged with the task of organizing the company's products and processes, but the daily priorities of quoting and production design inevitably interrupted the efforts. It is a 'Catch-22' situation – traditional inefficiencies in technical functions limit the resources available to overcome the inefficiencies.

b) A proven DCA technology platform is required

Standardizing products and processes is important, but it is necessary to package the results of the activity in a universally-available medium. Paper is inadequate and never timely. Spreadsheets, word processing documents, and isolated databases cannot integrate the job functions that depend on transcription of detailed technical data. Furthermore, the sophistication of an enterprise environment for managing both geometric and non-geometric product knowledge is beyond the typical capability of a manufacturer dedicated to profiting from its core competence. It made economic sense for 3L Filters to identify and select a proven platform ready to configure with the company's unique product knowledge.

c) Expertise is needed to configure the system

Finally, 3L Filters had to acknowledge that the process of capturing and automating the highly complex activity of design and costing was beyond its realm of expertise. The selected DCA vendor contributed over 15 years of experience in automating geometric assembly design, and demonstrated a thorough knowledge of engineering principles and manufacturing procedures. The vendor's staff knew how to capture, embed, and refine the unique product knowledge for 3L Filters 13 vessel families in the DCA platform. This extensive work was completed with a contribution of less than 200 man-hours of 3L Filters staff effort. The company had committed far more hours to past projects without success. Subcontract expertise made the difference.