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"Development of a Diesel Engine for the North American Light Truck Market"

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Detroit Diesel is owned by the Penske Corporation and is part of its transportation division. Detroit Diesel produces diesel engines ranging from 22 to 10,000 horsepower, and has annual sales of $2.3 billion. The company serves major markets including on-highway heavy-duty trucks, construction, industrial, mining, automotive, bus, marine, power generation, and military applications. Detroit Diesel employs over 7,000 people worldwide with an average seniority of 17 years. The company is best known for producing engines for class 8 types of heavy-duty trucks. Major heavy-duty truck customers include Peterbuilt, Western Star, Freightliner, Kenworth, International, Sterling, and Volvo. Detroit Diesel holds over 28% of the heavy-duty truck market share, with Cummins and Caterpillar being the closest competitors.

Detroit Diesel has over 11% of its business in the automotive segment. Manufacturing plants are located in Detroit, Michigan, Cento, Italy, and Curitiba, Brazil. Detroit Diesel also operates several remanufacturing facilities that rebuild used engines. The company's R&D efforts include research in new areas such as hybrid powertrains, piezo-controlled units, and noise and vibration reduction. Automotive product lines range from 1.4 to 5.3 liter engines, and are primarily in the European markets.

Diesel applications are expected to expand in the North American market due to the large increase in popularity of the SUV's, vans, and light trucks. The trend of these vehicles to increase in size is also affecting diesel engine demand. Diesel engines can reduce average fuel consumption and emissions output as required by new legislative regulations. Recent technological advancements have increased the performance of diesel engines, which greatly reduces the old stereotype problems of being noisy, difficult to shift, offensive smelling, smoky, and dirty. New diesel technologies are opening applications in the passenger car market.

The North American diesel market is growing in acceptance of diesel engines. A Quality Function Deployment (QFD) analysis was performed by Detroit Diesel to identify unique North American customer wants, which differ greatly from European customers. Low cost, drivability, emissions requirements, noise levels, and durability were major drivers in the design of the new diesel engine. Fuel costs were discovered not to be a major driver for customers to switch to diesel engines. The North American automotive market differs from the European market in both application and duty cycles. The extent of the differences was great enough that a new class of diesel engine was required in order to be successful.

The DELTA (Diesel Engine Light Truck Application) program was launched in September 1997 with a targeted prototype-in-vehicle completion date of the third quarter of 1998. The DELTA program goal was to design a light truck/SUV diesel engine specifically for the North American market, while compressing the design and development time from the typical 18 months to less than a year. The first engine ran in the lab in only 7-1/2 months after the start date of the project. The program started out with a clean sheet of paper utilizing the QFD analysis to design the engine with the customer in mind. CAD/CAM systems were used to enable cross-functional teams of designers, analysts, and manufacturing engineers to participate in the engine's development.

Detroit Diesel's core competencies lie in heavy-duty truck engines, and European style light-duty engines. Detroit Diesel combined their knowledge from these areas with research in noise/vibration reduction and other technologies to design the new class of diesel engine. Close relations with vendors and suppliers were also utilized in the engine's development. The quality function deployment provided clear identification of customer wants, and resulted in team buy-in of the project. The QFD was a hybrid analysis including both what the end consumer wants, and what the intermediate customer (automotive manufacturer) needs. A key success element was that the requirements were clearly identified, and did not change during the design process.

Several additional factors contributed to the team's success. The DELTA project team was co-located in a single area. All project requirements were documented on the LAN computer network. Significant project meetings included every engineer involved with the project, and also included the suppliers. Resources were front-loaded at the beginning of the project to overcome obstacles and address problems before they became embedded in the design. Upper management provided the empowerment and resources to ramp-up the design process from the beginning of the project.

Managing the program required a strict discipline in following and meeting project objectives. Adherence to risk management, scheduling, supplier involvement, cost controls and tracking, financial measurements, and manufacturing quality all became critical to the program's success. An emphasis was placed on predicting and forecasting to identify problems early in the design process. The team was not only empowered, but was also responsible and accountable for the project. The project was controlled by using the company's internal product development process of MRSP (Multi Stage Release Process). The MRSP process consists of separate stages of planning, doing, checking, and acting. Risk reviews were conducted between each major step. Throughout the project, a discipline was enforced at each step. Tracking tools were utilized to monitor critical time paths, bill of materials, number of engine parts, and other factors. One of the most critical success factors was discipline, forcing team members to stay to the plan and identify problems before they became serious.

Engine cost reduction was constantly enforced throughout the design of the engine. A system of compromises kept the project costs to target levels. The cost of more expensive design parts was offset by reductions in costs of other parts. Earned value measurement is a method of comparing the budgeted cost of work scheduled, the budgeted cost of work performed, and the actual cost of work performed. The earned value method was used to track costs and identify problems in advance, such as when there are not enough resources applied to the project.

The project team consisted of multiple cross-functional members. Manufacturing engineers were assigned directly to the design team. Assembly issues were considered up front, and incorporated into the design of the engine. There was an effort to minimize components and build-in features for assembly efficiency. Examples of innovations incorporated into the design of the engine are identical and reversible cylinder heads, identical intake and exhaust valve push rods, several parts combined into a single casting, single exhaust gaskets, single piece cores, castings instead of machined parts, and the elimination of valve seats, guides, and brackets.

The design analysis portion of the project was accelerated by several factors. Time restrictions did not permit standard methods of complete component design, then followed by analysis with iterations of improvements. New methods forced engineers to work with incomplete data and progressive models of increasing complexity. Preliminary designs were approximated for both analysis and concurrent design activities. As additional details became available, refinements were made to design of the components. Several concurrent iterations occurred until the process was complete. Three-dimensional solid modeling was also utilized to improve project designs. The modeling verified designs, permitted tooling and parts fabrication, and improved communications with suppliers. The cylinder block and heads were initially created through rapid prototyping techniques. Plastic models were first created to validate the integrity of the data. Laminated paper models were then fabricated for part visualization and verification, and to create the tooling to be used for the final product. The fuel system was developed in parallel to the engine prototyping. A fixture was built to permit the fuel system design to be tested off of the engine. As the engine prototype was completed, the fuel system was ready for actual testing on the engine.

The Durango was selected as the development and test vehicle because it was in the middle of the

parameters for the engine's target market. Modifications to the test vehicle were made as the first engine was being developed. The test vehicle was running in just 12 weeks after the first engine was built, and a calibration development period of 2-1/2 weeks was utilized. Immediately following the calibration period, the test vehicle was demonstrated to the press to both prove the engine performance, and verify that the design objectives were met. The reviews of the new engine were very favorable.

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