Engineering Resource

Engineering Services Since 1943

A technical newsletter for engineers and engineering managers

Number 34

Fall/Winter 1995

Gearing Up America's Defense

When an artillery piece is aimed and fired in modern warfare, many technologies must be brought together if the payload is to arrive at the right place at the right time.

To ensure increased accuracy for a new weapons system for the United States Army, RFA/ Minnesota Engineering was asked by the United Defense Limited Partnership (formerly FMC Corporation) to design two new, high precision gearboxes. They also had to be capable of operating in a hostile (battlefield) environment. This environment includes the shock and vibration induced from the launching of 155 mm artillery rounds.

The experimental weapons system, which will use a liquid propellant instead of conventional gunpowder, needed two distinct drive systems: an elevation drive to raise and lower the barrel, and a traverse drive to rotate the structure supporting the barrel.

"They wanted zero backlash - that is, zero clearance between two meshing gears," said Jim Rother, RFA project engineer. "The Army wanted that kind of precision so when the gun was pointed at a target there would be no 'play' or 'freedom' in the gun drive system; no possibility for it to 'over travel' and miss the target. United Defense brought us concept sketches and asked us to do the design and documentation."

RFA/Minnesota Engineering reviewed and evaluated the initial proposed concepts and concluded that there were alternative ways to accomplish the task. "With the client's approval, we did further conceptual work to better define and present these alternatives. Concurrently, the client did further study of the product specifications and determined that what was needed was minimum backlash, not zero backlash. There is a big difference! This allowed us more freedom in the design process to meet the specifications."

United Defense specified the space envelope in which RFA had

continued on page 2

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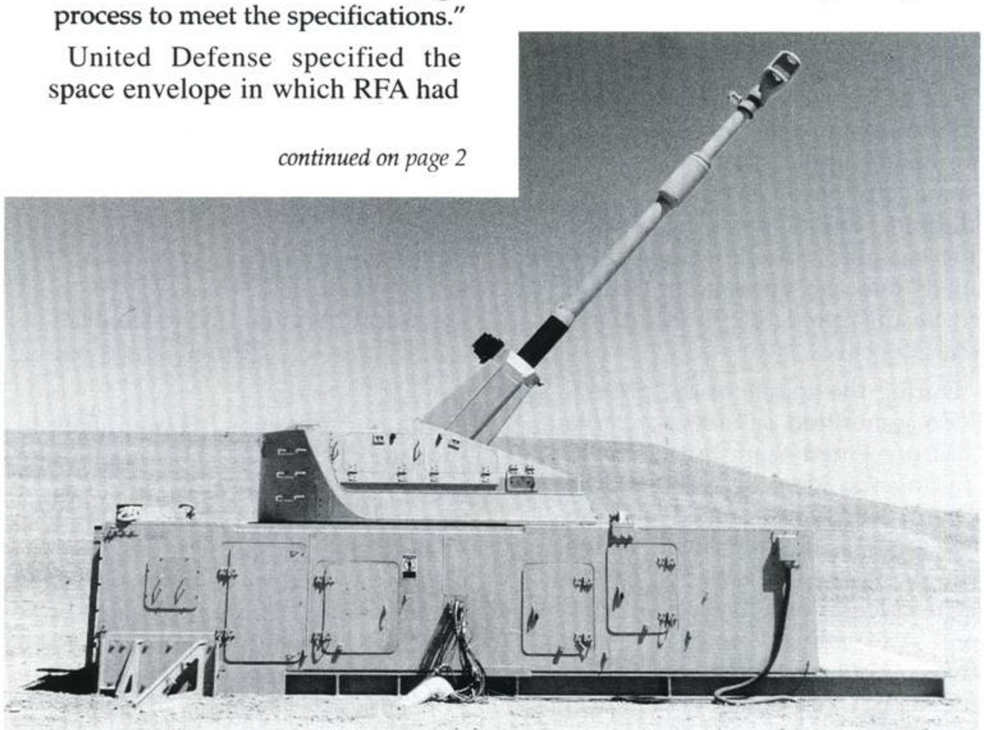
>
> **Scott Langlie,** United Defense Project Engineer



Regenerative Liquid Propellant Gun

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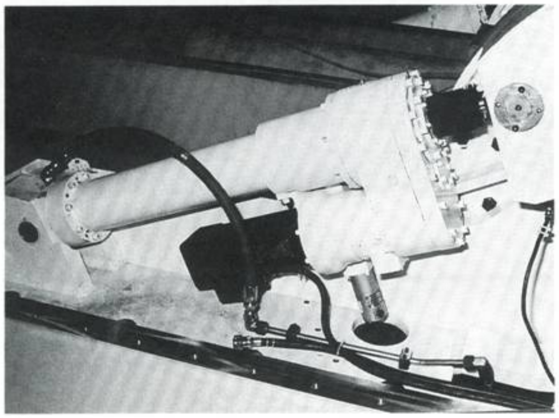
Gearing Up *continued from page 1*

to work for both drives. In addition, they supplied the traditional load and life criteria (including the duty cycle) plus the shock loads that it must withstand. One unique product specification was the "wind-up" or torsional stiffness allowable. Exceeding this requirement would have resulted in a weapons system with too much deflection adversely affecting the aiming accuracy and repeatability of target acquisition.

Furthermore, the job needed to be done within a strict time frame so that the drives would be finished and ready for installation into the prototype concurrently with the rest of the weapons system.

Regarding the gearing mechanisms, Rother said, "It's very heavy, very expensive, very limited in its applications." He went on to explain, "You could not use this in commercial applications such as automotive transmissions. It is an extremely conservative design because its intended use is a military application and can see some very nasty service, (i.e., battlefield conditions). Every time the weapon is fired, it puts shock loads into the drive train. It had to be designed to tolerate these shock cycles."

During the course of the project, RFA generated several concepts and presented them to the client. Taking the ideas selected by the client, RFA commenced making the working layouts from which the designs evolved. All of the gear calculations (both geometry and stress/life) were done using two computer programs (one written at RFA and one in general use by industry). All remaining calculations (bearing lives, shaft stress, deflections, etc.) were done using a combination of computer analysis



Elevation drive for the vertical barrel positioning.

programs and traditional manual analysis techniques. A three bearing shaft arrangement (statically indeterminate) was analyzed using finite elements techniques.

"This was a cooperative effort between United Defense and RFA. They were a good value because they worked as an extension of our own engineering staff."

Scott Langlie, United Defense Project Engineer

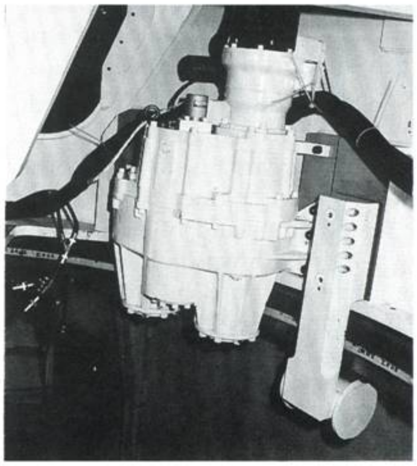
With one exception, parallel shaft spur gearing was used throughout the assemblies. Multiple gear sets were used in each drive, resulting in high overall reductions. One mesh consisted of helical gearing spring loaded to guarantee true zero backlash in that one instance. High quality gears were specified to ensure accuracy; the stress levels allowed the use of conventional gear steels and heat treatments.

The design and details were done on compatible CAD systems to make information and file exchange a certainty. The details were all prepared and checked to the client's standards. RFA performed a complete tolerance stack-up to ensure part and assembly fit-up. Both gear boxes were made and assembled by a third party. They had scheduled one week for assembly to allow time to resolve any problems. They completed the entire assembly of the traverse drive in one eight hour shift!

"Its significance was that it was designed all the way from a blank sheet of paper," noted Scott Langlie, the project engineer at United Defense. "RFA did a really good job of support for the design effort, and they bent over backwards to meet a difficult schedule. They had to supply resources and to work overtime to complete the detailed design packages."

"The end result," said Langlie, "was that the performance of the gun drives exceeded the requirements of the government. We have proven that in testing at the proving grounds in Yuma, Arizona. The performance of the gun drives is a success story," he continued. "We developed an elevation and a traverse drive from

continued on page 4



Traverse drive for the rotational gun positioning.

Cost Reduction Goal Achieved Through Redesign

A forty percent reduction in the unit cost of a popular industrial machine might seem like an ambitious goal for a manufacturer of floor maintenance equipment. Nevertheless, that was the challenge that Advance Machine Company brought to RFA/Minnesota Engineering. Advance's Minitriever, a long-time standard industrial floor sweeper, needed to be redesigned to meet market competition. It had been on the market since 1970, and, until the last several years, had been a high-volume selling item. Management noted that similar products had become available selling considerably below the price of the Minitriever.

According to Kurt Weimer, Chief Engineer at Advance, the company had three options: discontinue the product altogether, purchase a product for private labeling, or reduce the cost of manufacturing the current model. Advance decided they could bring down the cost by redesigning the product.

Weimer indicated that internal resources were not available at the time to develop concepts for redesigning the Minitriever. This situation led Advance to consider using the services of RFA/Minnesota Engineering. Except for using some industrial design services in the past, Advance had not worked with an outside firm that specialized in mechanical design. The relative simplicity of this product and the timeliness of the need encouraged the company to use this project as an experiment in determining the practical value of using outside engineering services. It could, in fact, lead to other projects with RFA, freeing up internal resources for other strategic business activity.

Minitriever

"RFA tends to have a big variety of products they work on," Weimer said. "That is advantageous to us, because our product would be new to them and they bring a new set of eyes to the design problem."

To initiate the project, Advance provided an artist's rendering of possibilities. RFA's Tom Teller, project engineer, and Kevin Brase, senior designer, functioned as the liaison team. They looked at the Minitriever, examined the competitive products, and proposed alternatives.

To achieve the client's goal of reducing the cost of this product, RFA focused on eliminating expensive materials and reducing the number of parts without changing the functional specifications. In the original model, the frame and hopper were constructed of metal and contained a lot of hardware. Besides adding weight to the product, this also resulted in significant material handling and assembly costs.

Plastic molded parts offered the best opportunity for reducing the number of parts in the machine. Three processes were investigated: injection molded, structural foam molded and rotational molded. The rotational molded process was chosen because it resulted in the best combination of part and tooling costs. Furthermore, Advance already has a line of machines constructed with rotational molded parts, and this would conveniently tie the Minitriever into that family of products. Advance currently produces rotational molded parts for their other products.

Cost Reduction *continued from page 3*

Project engineer Tom Teller reported that it was necessary to overcome significant tolerance buildup inherent in rotational molding technology. Tolerance build up of 3/4% to 1 % per inch of length is common. The design had to allow for the tolerances but yet maintain the critical relationship between the broom and the sweep lip of the hopper.

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Kurt Weimer, Chief Engineer, Advance Machine Company

As an example, if the hopper is 18 inches long and the mating frame is 18 inches long, the potential tolerance build up may exceed 1/4 inch. "To minimize the tolerance build up, the parts were designed with common locating features close to the critical areas of each part. This resulted in good control of the mating parts and allowed the use of the rotational molding process," said Brase.

In addition to his mechanical redesign efforts, Brase also offered Advance some industrial styling options for the new Minitriever.

When the project was completed, the redesigned Minitriever had approximately one hundred fewer parts, and its weight had been reduced by ten percent. This significantly reduced material handling costs. It took less than four months to complete, and Advance achieved its cost reduction goal through redesign.

Kurt Weimer was pleased with the results of the collaborative effort between RFA and Advance. The newly designed product has also been added to Nilfisk's own product line, the parent company based in Denmark. "Because of the machine's high quality, Nilfisk had to increase the sales forecast by 25 percent," Weimer said.

Gearing UP *continued from page 2*

concept to detailed design, to fabrication of hardware, and we developed it against very difficult requirements. Basically, it was a nine month effort."

Langlie emphasized the "we" configuration of the project's team members because it was a cooperative venture between United Defense and RFA. Describing the effort as a very good match for both companies, he noted, "We had common computer systems, and that helped a lot. RFA did really good work. They were a good value because they worked as an extension of our own engineering staff, and we treated them like an extension of our engineering group. They came up the learning curve quickly. They knew where we were coming from, and they knew where we needed to be."

RFA's Jim Rother summarized the project: "We did the concept work in four weeks and went from start of design to finished drawings in five months. They had completed drives in nine months from the day we started. We met the schedule. They got their gear boxes on time."

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