ADVANCED SLARETTE DELIVERY MACHINE

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ABSTRACT

SLARette[1] equipment, comprising of a SLARette Delivery Machine, SLAR Tools, SLAR power supplies and SLAR Inspection Systems was designed, developed and manufactured to service fuel channels of CANDU 6 stations during the regular yearly station outages.

The Mark 2 SLARette Delivery Machine uses a Push Tube system to provide the axial and rotary movements of the SLAR Tool. The Push Tubes are operated remotely but must be attached and removed manually. Since this operation is performed at the Reactor face, there is radiation dose involved for the workers.

An Advanced SLARette Delivery Machine which incorporates a computer controlled telescoping Ram in the place of the Push Tubes has been recently designed and manufactured. Utilization of the Advanced SLARette Delivery Machine significantly reduces the amount of radiation dose picked up by the workers because the need to have workers at the face of the Reactor during the SLARette operation is greatly reduced.

This paper describes the design, development and manufacturing process utilized to produce the Advanced SLARette Delivery Machine and the experience gained during the Gentilly-2 NGS Spring outage.

1. INTRODUCTION

The Advanced SLARette Delivery System was designed to enhance the performance of the Mark 2 SLARette System by simplifying the delivery machine while improving the capability and reliability of the hardware.

The advanced design was first conceived in February of 1994 while studying methods to decrease direct operator involvement at the Reactor face. The primary focus of the early development was the replacement of the manually manipulated Push Tubes with a fully automated, remotely controlled, SLAR tool delivery system. It was from these early design ideas that the Advanced SLARette's telescoping Ram was developed.

The Advanced SLARette Delivery Machine incorporated most of the existing Mark 2 SLARette Delivery Machine hardware. Taking advantage of the previously qualified design significantly reduced both development and manufacturing costs. An additional benefit of the integrated design was that the complete Mark 2 SLARette Drive and Push Tube system could still be used, if it were found to be advantageous to do so.

The new machine consists of a telescoping Ram assembly, axial and rotary Drive Motors, Control Computer, Support Table and Pedestals. The original Mark 2 SLARette Primary Turret, Closure Plug removal Tool, Transition Tube, Secondary Turret and Calibration Tube are maintained.

The SLAR Tool is moved axially along the fuel channel by moving the Ram assembly which is connected to a ball screw driven by a DC brushless motor. A second DC brushless motor rotates the Ram. The SLAR Tool motion is computer controlled by custom software written in 'C' running on an industrially grade fault tolerant 486-PC. This computer forwards the tool position data to the SLAR Inspection system computer.

The duration for the design and development program of the Advanced SLARette Delivery Machine including the full system integration, proof, and acceptance testing was 14 months. The short development time of the Advanced SLARette System can be attributed to the engineering tools and techniques utilized throughout the project.

The completed Advanced SLARette Delivery Machine and System was shipped to the Gentilly-2 NGS in April of 1995. The Advanced System then completed a very successful, thirty day, campaign in May of 1995. SLAR operations were completed on 45 channels in that period.

2. DESIGN PROCESS

The single most unique aspect of the Advanced SLARette Delivery Machine's design, that contributed to the successful operation and the short development time, was the engineering design process. The use of a Concurrent Engineering Team, utilizing some of the most advanced and powerful CAD/CAM tools available, began shortly after the design concepts were submitted. This approach was endorsed by AECL management and the client, Hydro Quebec, with the proviso that periodic reviews of progress would show some significant advantages over the tried and true, 'Pen and Paper' design methods used previously. A potential drawback was that the use of CAD/CAM and concurrent engineering was essentially unproved within AECL.

2.1 Concurrent Engineering Team

A team was assembled to cover the anticipated skill requirements of the project. The team consisted of the following positions; Coordinator, Design Engineer, Mechanical Technologist, Mechanical Technician, CAD/CAM Specialist, Draftsperson, Electrical Engineer and a Electrical Technologist. The core design group that developed the conceptual design, were the Design Engineer, the Mechanical Technologist, the CAD Specialist and the Electrical Engineer. It was from these early conceptual design meetings that the full concurrent engineering design process evolved.

2.2 Design Tools

The mechanical design work of the Advanced SLARette Delivery Machine was done using Parametric Technology Corporation's CAD software 'Pro/Engineer' release 13.0. The software used parametric modeling methods to generate true solid 3-D models, from conceptual sketches, that allowed the design team to quickly 'see' the components individually and more importantly, assembled to their mating parts (Figure 1). The software also highlighted any interference or design problem that existed because the models could be rotated, shaded or 'sectioned' on screen and viewed from any direction. The mechanical properties of the model components were readily calculated by the software and used to finalize the other design parameters of the system.

As the overall size and complexity of the assembled model continued to grow, the power of CAD software tools became obvious. The software could easily assemble the model components into different design configurations by altering the assembly parameters or conditions used. The simulated 'animation' was used extensively to complete the detailed design and determine the final configuration of the Advanced SLARette Delivery Machine.

During the design process, changes were necessary. Some were due to design restrictions or material limitations while others were client requested, usually to make something more suitable to the site operation of the system. The CAD software maintained the data base and the associative nature of the model components and mechanical drawings. This allowed all changes to be made with the assurance that they would be reflected in both the detail drawings and the models.

Upon completion of each model component, one of two things occurred. The model/part geometry was either IGES[2] transferred directly to the CAM specialist for manufacture on AECL's CNC machine tools; or mechanical drawings were completed and issued to outside suppliers for quote and eventual manufacture.

At various points during the mechanical design phase, prototypes were manufactured to demonstrate the design and to prove out any of the conceptual concerns that still existed. These prototypes were also important to physically display the design process because a very limited amount of hardware had been manufactured, or was necessary, by the half way point in the design process.

2.3 Concurrent Activities

Several other activities occurred concurrently while the mechanical design work continued. These included; the refurbishment and modification of the existing Delivery Machine hardware; procurement of the new designed components and the vendor supplied hardware; and the extensive electrical engineering work that was required.

The instrumentation and control system for the Advanced SLARette Delivery Machine was developed using consultations and planning meetings between the concurrent engineering team staff. The challenge, for the electrical engineering staff, was to rapidly integrate a still evolving mechanical system design into the existing Mark 2 SLARette instrumentation and computer system via a completely new control interface. The control software would have to accept operator inputs, drive the axial and rotary positional control motors of the Advanced SLARette Delivery Machine, and simultaneously feed back the encoder information to the other SLAR computers.

To achieve the design goals, the electrical design specifications and hardware selection were completed early in the design process by making conservative equipment sizing choices. This left enough time for the development of the control algorithms, writing the computer programs and proof testing the hardware and software. The concurrent engineering team approach allowed the mechanical and electrical engineering systems to be fully compatible as the development program ended and the designs were fixed.

3. DESIGN DESCRIPTION

The Advanced SLARette Delivery Machine was assembled from existing hardware, newly designed components and pre-engineered catalog items. The need to integrate the existing Mark 2 hardware into the final design of the Advanced SLARette was a major design criteria. Other contributing criteria were simplicity, reliability and modular design. The use of the pre-engineered catalog items was key in keeping the limited design time available for new components.

The design requirement of full remote control of SLAR tool operations once the Delivery Machine was latched onto the fuel channel and the closure plug was removed, was achieved by integrating these new components; Ram Tube, Shuttle, Ball Screw, Support Table and Lifting Pedestal assemblies (Figure 2).

3.1 Ram Tube Assembly

The Ram Tube assembly was the most complex and challenging portion of the Advanced SLARette Delivery Machine design. A considerable effort went into conceptualizing and developing a workable telescoping ram and latch design. The need to utilize a three stage Ram assembly grew from the space limitations of the CANDU 6 vault, existing Mark 2 SLARette component sizes, SLAR Umbilical Cable diameter and the four inch pressure tube inside diameter.

Components of the Ram, once modeled, were studied and manipulated with functionality, fit and manufacturability being continually reviewed. It was from these models that the first Latch Block and Ram Tube prototypes were manufactured. Their successful operation helped to demonstrated the viability of the new design.

3.2 Shuttle Assembly

The Shuttle Assembly was made up from a base plate with side supports and a spherical bearing pillow block. The pillow block held the Ram assembly in position on the center line of the machine while providing rotary freedom of movement for the drive. The rotary drive motor was geared to the Ram tubes via a timing belt and pulley system that was easy to maintain. The entire Ram and Shuttle assembly was moved by a Ball Screw Drive Nut which was fixed to the Shuttle.

3.3 Ball Screw Assembly

The unique feature of the Ball Screw Assembly and axial drive motor was that it was mounted directly to the Support Table on linear bearings that allowed the entire drive train to float. This meant that the drive system was always connected and that manual channel connection operations could be completed without further set-up of the axial drive hardware.

3.4 Support Table

The Support Table was designed to accept both the Mark 2 and the newly designed Advanced hardware onto one standard base. The design incorporated several features that allowed for both simple setup and reliable operation. The use of linear bearings and tracks on all attached components made the whole system nestable. This enabled the delivery machine to be compacted lengthwise so that the table frame was the longest fixed item. These features allow the Advanced SLARette Delivery Machine to be installed into, and removed from, the SLARette shielding cabinet using the reactor transfer hall. Once the delivery machine is installed, the shielding cabinet is lifted and bolted to the Fueling Machine bridge in the maintenance area. The system is then ready to go into service.

3.5 Lifting Pedestals

Two lifting pedestals were used to adjust the alignment of the Support Table to the end fitting center line. The pedestals utilize screw jacks, driven by DC motors, to provide the fine and coarse height adjustments. The motions could be either linked together or run independently. This was achieved by using motor synchronizers and a programmable control unit. The operators were supplied with a push button input pendant.

4. SYSTEM PERFORMANCE

The Advanced SLARette Delivery Machine was used at the Gentilly 2 site in the Spring 1995 for the first time (Figure 3). During the outage period Advanced SLARette was available from April 30 until May 29. The spacers were successfully repositioned on all 45 fuel channels worked upon in this period. The average channel processing time (cycle time) achieved was 7.75 hours from the latched on configuration to the disconnect point. An average of 1.6 channels were completed per day (45 channels in 28.5 days) due to other activities that needed to occur. These included fuel shuffling which is required for the SLARette process as well as Station critical path work on the Steam Generators and other maintenance work The Advanced SLARette Delivery Machine performed very well during the Gentilly 2 outage. There were some minor problems but the design allows for easy maintenance of the equipment.

Benefits of new delivery system include; very fast channel processing times; no full time "In Vault" support staff required, greatly reduced radiation dose exposure; improved operational capabilities; no time delays associated with push tube changes, personnel shift changes or communication problems and decreased support staff training. Also, all SLAR tool position functions including rotational and axial tool positioning were controlled by a single operator, through a 486-PC based computer.

5. SUMMARY

Overall, the system performance was even better than expected with the prototype Advanced SLARette Delivery Machine. The use of concurrent engineering and CAD/CAM proved itself time and time again during the development program and the outage. The machine achieved its primary design goal by greatly reducing the accumulated radiation dose picked up by the Gentilly 2 personnel.

All the improvements and benefits combine together to make the Advanced SLARette Delivery system a very good overall performer in the "SLAR" family of maintenance equipment.

[1] SLAR = Spacer Locator And Relocator

[2] IGES = Initial Graphics Exchange Standard

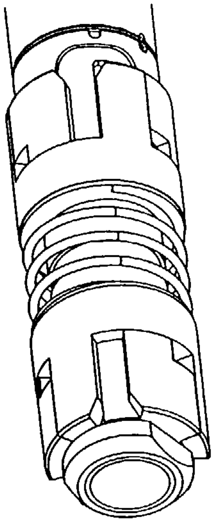

Figure 1. Latch Block Model

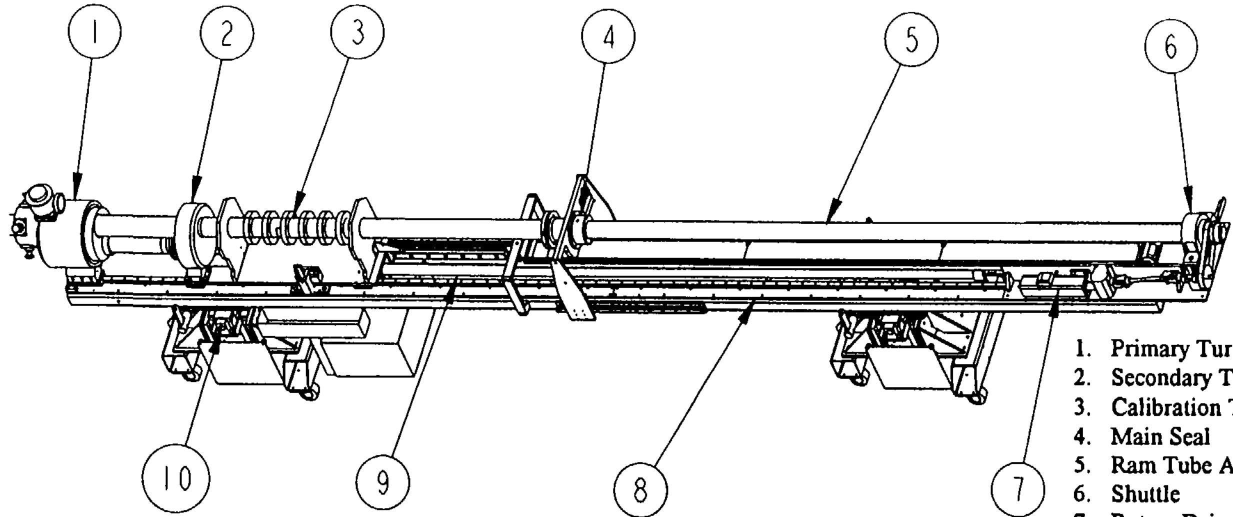

Figure 2. Advanced SLARette Model

1. Primary Turret
2. Secondary Turret
3. Calibration Tube
4. Main Seal
5. Ram Tube Assembly
6. Shuttle
7. Rotary Drive Motor
8. Support Table
9. Ball Screw Assembly
10. Front Lifting Pedestal

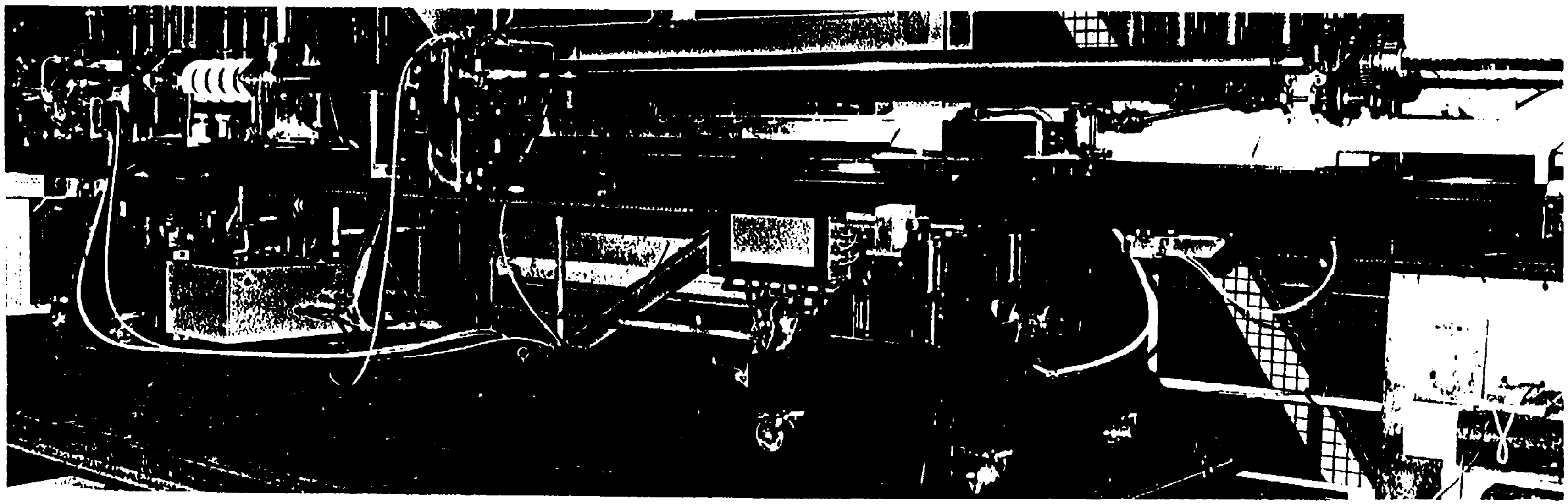

Figure 3. Testing of Prototype Machine