THE MANUFACTURING ROLE IN FUEL PERFORMANCE

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ABSTRACT

Manufacturing companies have been involved in the CANDU fuel industry for more than 40 years. Early manufacturing contributions were the development of materials and processes used to fabricate the CANDU fuel bundle. As CANDU reactors were commissioned, the manufacturing contribution has been to produce economical, high quality fuel for the CANDU market.

INTRODUCTION

This year, Zircatec is celebrating the 40th Anniversary of manufacturing for the nuclear industry in Canada, at our facilities in Port Hope and Cobourg, Ontario.

Anniversaries are traditionally a time to examine the past and the future and this 40th Anniversary is a good time to share, from a manufacturing view point, our role in fuel performance.

We have had, over the last 40 years, 3 owners of the Port Hope plant.

- AMF Atomics - 1957 - 1964
- Westinghouse - 1964 - 1988
- Zircatec Precision Industries Inc. - 1988

During the first 15 years our role was to develop processes for fuel manufacturing starting from a conceptual fuel bundle design. Through an interactive process which combined bundle design refinement, manufacturing procedure development, the development of inspection techniques and manufacturing equipment design and development, the technology for a unique Canadian fuel bundle was developed. This design was evaluated in test loops in the NRX/NRU research reactors and in early power reactors such as NPD and Douglas Point. This experience led to further refinements in bundle design and manufacturing techniques which enabled the high volume manufacture of fuel bundles to exacting quality standards.

The result was the design evolution of the three styles of CANDU fuel bundles that we have at present; the Pickering 28 element bundle, the Bruce/Darlington 37 element bundle and the CANDU 6 37 element bundle.

The last 20 - 25 years have been a period of growth and new challenges for fuel manufacturing as new CANDU reactors were commissioned world wide.

MANUFACTURING ROLE

Development

The early collaboration between the designer, AECL, and the manufacturers paved the way for the manufacturing role today. AECL designed the reactor and the fuel bundle. Through contracts with industry, the manufacturers developed the processes and equipment to build the bundles.

This collaboration produced a set of design requirements in the form of Technical Specifications for a fuel bundle which define the materials, the components and the fuel bundle. The design requirements set limits for mechanical strength, hydraulic resistance, compatibility with fuel handling, and power output. Additionally, computer codes were developed to assess the bundle against the design requirements, and to model fuel performance.

In the development period many manufacturing processes were tried, tested and finally proven to be sound technology and incorporated into the CANDU design. These methods are used today by manufacturers of CANDU fuel.

- brazed appendages using beryllium metal pre-placement
- pressing and sintering high density UO_2 fuel pellets
- resistance welding of element closure plugs (end caps)
- resistance welding for bundle assembly
- application of Canlub coating in fuel elements

Manufacturing

The role of manufacturing has been to work within the limits of the design requirements. This has required detailed manufacturing drawings for components, and assemblies to enable the design and development of equipment to build the components; the sub-assemblies and the fuel bundles that conform to the design requirements. In addition to manufacturing drawings, product specifications were developed to better define the requirements of components in manufacturing terms and to determine the quality level necessary to assure compliance with the design.

The result is that each manufacturer produces a fuel bundle that meets the design requirements but is characteristically unique to that manufacturer. The "pride of ownership" is part of the force to continually produce a better bundle.

MANUFACTURING CHANGE

The significant change in the last 20 - 25 years has been an increase in production rate from about 10 or 20 bundles/day to about 200 bundles/day. The emphasis for the manufacturer has changed from a development role to that of a high volume and high quality producer.

Table 1 lists some of the manufacturing operations and the quantity of parts produced for a manufacturing rate of 200 bundles/day. As can be seen, the annual rate of the operations listed exceeds one million components for each of the significant operations.

The increase in production level and the competitive environment in Canada has required significant developments in manufacturing technology. The design of equipment used for manufacturing had to be improved to increase productivity and quality of all components. The equipment changes have been to improve:

- handling of the components
- quality of the components
- reliability of the equipment
- inspection methods
- health/safety of workers
- inventory control
- data collection

Additionally, as a manufacturer in Canada, we are required to change our production line to any of the three fuel types a number of times each year. It is essential to design equipment that is versatile for the change over.

MANUFACTURING CHALLENGE TODAY

It is our overall goal, as a manufacturer, to ensure that our customers do not incur increased operating or administrative costs due to the manufacturer. Our goal applies to total quality satisfaction. It includes reports, data disks and packaging as well as bundle recall or bundles defecting in the reactor.

Most of our goals can be measured in a timely manner by customer feedback. However, feedback which will help us achieve one of our most important goals, "zero reactor defects" due to manufacturing, is delayed by 1 - 3 years due to inventory, residence time in the reactor and the subsequent post irradiation inspection. It is imperative that a manufacturer diligently pursues the goals in all aspects of manufacturing in order to avoid the unpleasant surprise of manufacturing related reactor defects.

How well we do in meeting our goal, will reflect how well we do in business; our reputation and our future is at stake.

Should any manufacturer of CANDU fuel around the world fail to meet their customer's expectation; the reputation of all CANDU reactors is adversely affected; thus, to some extent all fuel manufacturers are affected.

MANUFACTURING QUALITY

The Contract

The contractual requirements for fuel bundle manufacturing have been to CSA Quality Standard CAN3-Z299.1or .2. To comply with these requirements we have written policies, procedures and work instructions. We demonstrate by audits to our customers that the quality requirements stated in the contract are being complied with. The compliance with the contractual requirements provides a measurement but in itself does not ensure we will meet all our goals.

Working to PPM

It has been recognized that CANDU fuel has experienced a low defect rate due to manufacturing causes[1] that equates to parts per million (ppm) defective components.

Few industries talk in terms of defects in the ppm level. When you look at Table 1 you can quickly determine, that to meet our goal, we must as a manufacturer apply ourselves to work to better than ppm defectives. This quality level must be built into the fuel bundle by the manufacturing equipment, the process and the employees.

We can simplify the task of working to ppm levels and apply our efforts in the most effective manner when we define the following:

(1) Defect - a deviation that may cause a measurable incident for the customer

(2) Non-conformance - deviation that will not cause a measurable incident for the customer.

Determining the cause of defects and nonconformances by Fault Tree Analysis is a significant step to determine which deviations one must eliminate or reduce by manufacturing methods or by employing inspection methods to segregate the deviation with an excellent confidence.

example: - The sorting process at ultrasonic inspection of tubing for lap defects allowed about 2 ppm of the laps into production that were later discovered by the helium leak test. Changing from a manual to an automated sorting system has not allowed a helium leaking lap defect in 10 million tubes.

Quality Improvement

Manufacturing quality is not only a matter of meeting the specification. Within a manufacturing organization there is

(1) the need to constructively criticize from within to improve

(2) the need to constructively answer this one question "what if ?" to obtain the best machine design and the best employee training program.

In order to achieve continuous quality improvement we must measure our current performance in order to establish new performance objectives.

Typical quality indicators used to measure performance are:

- quality deviation at each operation (nature, quantity, trends)
- process deviations at each operation (nature, quantity, trends)
- tooling life trends
- preventative maintenance observations
- process control data
- audit findings
- customer feedback

Improving Equipment

The quality indicators are thoroughly analysed by production, process engineering and quality assurance and are used to establish the root cause at production and quality concerns. The analysis becomes an input to the equipment designer in order to modify or replace manufacturing or inspection equipment to meet todays' production and quality requirements.

On the positive side, the analysis of the quality indicators may show there is no immediate improvement required. In this case the analysis helps to confirm or re-establish controls used to maintain the quality level.

Employee Training

Equally as important as machine design is employee training. All machines are created by employees and all machines interface with employees. Zircatec has adopted the philosophy of "Building Nuclear Excellence" for one of our goals . To meet this goal employee training goes further than how to do the job. All employees need to understand the company policies, the products and the quality system requirements. Each employee needs to understand the importance of their job. To reinforce this training aspect for all employees, one of the methods we have adopted is to organize an ongoing number of Work Awareness workshops that bring employees together to interact on a number of topics. Keeping the groups small, 10 - 20 employees, encourages discussion between the speaker and employees. The discussions result in two-way communication to increase awareness of all participants.

SUMMARY

1. The manufacturing role has changed from development to production.
2. The manufacturing role must be to total customer satisfaction. This role is much more than just meeting the specification, it must be to "Building Nuclear Excellence".
3. The manufacturing role, as one of the three partners in the CANDU industry, along with the designer and the utility, is to make CANDU succeed.

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TABLE 1

Production Rate -

200 37-Element Bundles/day

Manufacturing Operation	Quantity per day	Quantity per year (millions)
Tube manufacturing	7,400	1.6
Pellet manufacturing	222,000	49.0
Brazing .8mm spacers	26,400	5.8
2mm spacers	4,800	1.1
bearing pads	10,800	2.4
End Cap Welds	14,800	3.2
End Plate Welds	14,800	3.2