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PULL-PRODUCTION IN REPETITIVE REMANUFACTURING

D. W. McCaskey Jr.

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Pull-Production in Repetitive Remanufacturing

By Donald W. McCaskey, Jr., Ph.D, CFPIM

In the past, production activity control practices in most repetitive remanufacturing facilities resembled those used in intermittent production operations. These operations were characterized by large amounts of work-in-process (WIP), frequent work stoppages due to part shortages, excessive overtime, low product velocity, informal scheduling between dependent operations, low employee and management moral, and a lot of wasted time, material, labor, and space. Improvement in production activity control (PAC) methods for repetitive remanufactures has been hampered by uncertainty in: supply of incoming assets, configuration of assets, process times to refurbish assets, and yields in reclamation processes. Collectively these uncertainties make shop floor operations seem uncontrollable. However, one United States Army depot has taken on the challenge. Through management supported, cross-functional teams, the Tooele Army Depot has designed and implemented pull-production systems for two of its major products, with several others to follow. This article presents a generalized version of Tooele's pull-production system and highlights design characteristics which are specific to remanufacturing applications. First, it is necessary to define the repetitive remanufacturing environment.

An Introduction to Repetitive Remanufacturing

In order to understand how pull-production can meet production activity control needs of repetitive remanufactures, one must first understand their operating environment. **Repetitive** implies that products, or families of products, have sufficient volume and capacity requirements to justify dedicating a cross-section of plant resources to their production. These resources might be dedicated to a particular product for only a few weeks, or up to several months each year. The same or similar products may be remanufactured year-after-year. Repetitive remanufacturing is distinct from low-volume remanufacturing where each production unit has high capacity requirements. In low-volume remanufacturing, capacity requirements may vary greatly between units, thus suggesting a project approach to production planning and production activity control.

Remanufacturing is defined as "an industrial process in which worn-out products are restored to like-new condition." (APICS Dictionary, Seventh edition.) This restoration process typically involves three general processing steps: disassembly, reclamation, and reassembly (see Figure 1).

Disassembly takes used assemblies, often times called assets, and tears them down into components. Components are piece parts or subassemblies which themselves may be disassembled later. These components commonly fall into one of three categories: scrap, reworkable, or serviceable. Components may be scrapped because of normal wear or damage incurred during use, damage incurred during disassembly, or a policy decision to routinely replace specific components with new parts. Reworkable components are those judged to be repairable in reclamation processes. Serviceable components are those which are reusable as-is. In most remanufacturing plants, disassembly operations provide the first opportunity to accurately estimate material and processing requirements to remanufacture an asset.

Reclamation takes repairable components from disassembly and perform the necessary operations to return them to a serviceable state. Some parts are scrapped during processing, others are scrapped because they were not repairable in the first place. Reclamation is an internal customer of disassembly, and a supplier to reassembly. **Reassembly** uses reclaimed parts, supplemented with new parts, to build end-items for stock or shipment.

In a repetitive remanufacturing environment it is common to have high-value components which are too expensive to replace. These components are commonly called **control items**. If a control item is scrapped or missing, then another asset is inducted into disassembly to provide a replacement. For example, suppose you are responsible for production planning and control of a new program to remanufacture one-thousand (1000) multifuel engines for 2.5 ton trucks. Further suppose that the engine has one control item, the cylinder block. During past programs eight percent (8%) of the cylinder blocks were scrapped due to unrepairable cracks or excessive wear. This implies that you will need to induct about 1087 used engines into disassembly to get 1000 serviceable blocks (1000/(1-0.08)). It also means that there could be 87 extra sets of used parts in the system.

With extra parts to choose from, components with scrap rates lower than the control item will have **excess** parts available, while components with higher scrap rates will still need to be supplemented with **new parts**. Determining what parts are excess and what parts need to be ordered is a major challenge in remanufacturing.

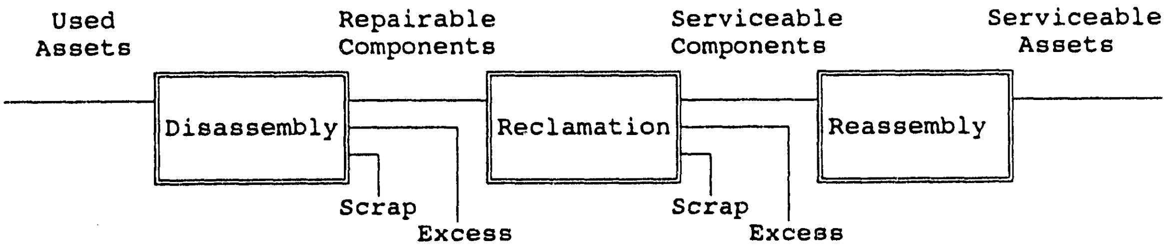

Figure 1. Basic Remanufacturing Process Flow

Uncertainty - The Major Problem in Remanufacturing

Uncertainty is inherent to almost every facet of the remanufacturing environment.

- Receipt quantities and timing of incoming assets are difficult to forecast, in part because they are often based on equipment failure rates and equipment retirement schedules.
- Upon receipt, some assets may be missing major components or subassemblies.
- Processing requirements and replacement material requirements may vary widely between similar assets, depending on their condition.

The effects of these and other factors on shop floor operations are detrimental and unavoidable.

Shop floor conditions in remanufacturing operation are highly dynamic and require an equally dynamic production activity control system. For example, consider again your hypothetical program for one-thousand (1000) truck engines. Suppose the oil cooler base for this type of engine has experienced a scrap factor of twenty-four percent (24%) on recent programs. If about 1087 engines will be disassembled, you should receive about 826 serviceable oil cooler bases from your internal supplier (1087(1-0.24)). The additional 174 oil cooler bases (1000-826=174) are ordered from an outside supplier and are received before the start of the engine program. Months later you are halfway through the program when you are approached by an unusually cheerful production supervisor. He informs you that the scrap factor for cylinder blocks has been cut in half as a result of a new metal stitching capabilities being proven-out on your engine program. Now, instead of disassembling 1087 engines to get 1000 serviceable cylinder blocks, only about 1042 will be needed. Your first reaction is to celebrate with the supervisor over the process improvement and the resulting cost reduction. After all, a part saved is like money in the bank. Its not until you get back to your office that you realize your dilemma. Since fewer assets are being disassembled, your internal supply of components will be reduced, and you are probably going to be short 34 oil cooler bases and several other components as well (see Table 1).

	The Plan: Cylinder Block Scrap Factor Planned at 8%	Scenario #1: Actual Scrap Factor Averages 4%	Scenario #2: Actual Scrap Factor Averages 12%
Program Quantity	1000	1000	1000
Induction Quantity	1087	1042	1136
Serviceable Oil Cooler Bases (76%)	826	792	863
Purchased Oil Cooler Bases	174	174	174
Net Requirement	0	34 (short)	-37 (excess)

Table 1. Effects of Deviations Between Planned and Actual Scrap Factors

Significant deviations between planned and actual scrap rates, process times, and other planning parameters are inevitable in remanufacturing. A dynamic production activity control approach is needed to provide early warning of possible problems and thus avoid endless fire-fighting.

A Basic Pull System for Repetitive Remanufacturing

Considering the repetitive nature of their production, Tooele Army Depot developed a basic pull-production system to coordinate their shop floor activities and provide early detection of problems. The system uses two types of pull-triggers: transfer triggers to authorize material movement, and production triggers to authorize generation of another transfer lot-size (see Figure 2). Once established, these triggers (in combination with the Master Production Schedule) automatically coordinate material movement and production at all stages of the remanufacturing system.

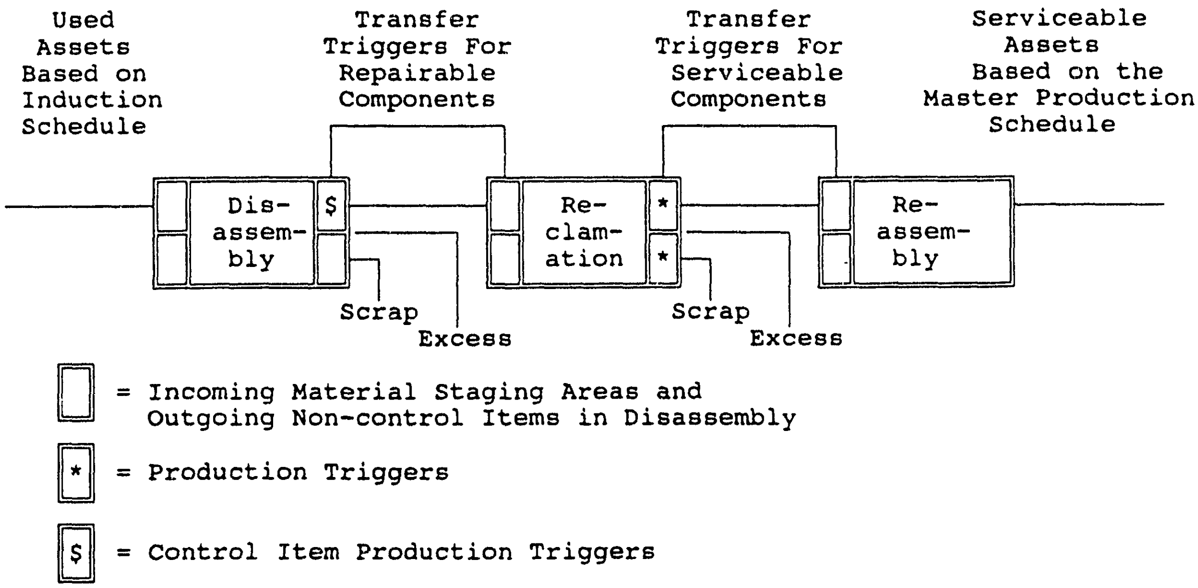

Figure 2. A Basic Pull-Production System for Repetitive Remanufacturing

It is important to note that this system does not have Just-In-Time production as its goal. The objective is to coordinate production operations. Later, as systemic problems are resolved, operations may be coupled more tightly.

The unique features of this system include queues for staging non-control items on the output side of disassembly. Since only control items can trigger disassembly of assets, quantities of repairable non-control items will either build-up or dry-up depending on how their actual scrap rates compare to that of their relevant control item. (The relevant control item for an asset is the control item which is expected to have the highest scrap rate.) For example, the relevant control item for your hypothetical engine is the cylinder block. If oil cooler bases are being scraped 24% of the time, but cylinder blocks are only experiencing an 8% scrap rate, then you will repeatedly run out of oil cooler bases in disassembly. When a material handler arrives in disassembly with a transfer trigger for oil cooler bases, and the quantity available is less than the transfer quantity, the shortage is made-up from stock. This practice of letting new parts trickle into the system helps maintain a balanced material flow, as opposed to having disassembly work far ahead of other processes and leaving new parts untouched until the very end of a program.

On the other hand, suppose your engine has a flywheel which is almost never scrapped. Before long it will become obvious that you have excess WIP for this item. Early identification and disposal of excess prohibits adding value to parts which are not needed to support production.

Another rare feature of the system is its use of shop floor scrap reports to provide early warning of potential parts shortages. Daily scrap reports are added to the database and periodically the following calculation is performed for most items:

$$PUR = 1 - [(1 - SR_{SI})/(1 - SR_{CI})]$$

where, PUR = Percent Unit Requirement,

SR_{SI} = the actual Scrap Rate of the Subject Item, and

SR_{CI} = the actual Scrap Rate of the relevant Control Item.

If a component's PUR value is positive, then new parts will probably be needed to meet production requirements. If it is negative, then there will probably be an excess of the subject item. Program, master production schedule or customer order quantities (whichever is appropriate) are multiplied by the PUR and the result is compared to on-hand plus on-order quantities for the component. Desired safety stock levels are also considered at this point. Results of the comparison will determine roughly how many components are to be ordered or excessed. For a quick indication of trouble, the PUR can be compared directly to the replacement factor used in planning.

Conclusions and Credits

Successful production activity control systems are not discovered, they are created. In the case of Tooele Army Depot their pull-production systems were created through the hard work of cross-functional teams, populated with empowered employees. Several factors contributed to their success, including: thorough project planning, careful team formulation, proper education and training programs, manual simulations to test ideas and convey concepts to others, and help from outside experts. All these factors were important, but management support stands alone as the key enabling factor. Even with a great system design, implementation will fail unless you have:

- Top-management's visible support and understanding of the production activity control system's objectives.
- Middle-management's support, sharing a common vision and providing a consistent direction for the teams.
- Supervisors' and lead peoples' support, encouragement and participation, especially during final design and implementation phases.

The depot is currently extending their pull-production system to encompass other operations. Success can never be guaranteed, but considering the support factors they have in place, their chances of success are excellent.

Donald W. McCaskey, Jr., Ph.D, CFPIM, is a consultant with Battelle in Columbus, Ohio, specializing in materials management.

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