

New Generation Automated **Fastener Feed Systems**

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ABSTRACT

New fastener feeding approaches are compared with existing bowl feeders and hoppers.

- A "smart" hopper for headed fasteners and slug rivets combines a fastener sensor with robust mechanics.
- The coiled tube magazine system uses briefcase sized magazines with integral escapements. These magazines can handle slugs or headed fasteners.
- For slug rivets, a magazine based system uses off-line loading to eliminate system slow-down due to debris or bulk fastener problems.
- A system for collars and nuts can feed various fasteners down a flexible tube to the installation point, requiring ten seconds to change fasteners.

INTRODUCTION

The four new fastener feed systems presented will be evaluated against four criteria: Applicability; Reliability; Upgradability; and Overall System Cost. The four systems will then be compared against existing bowl feeder and traditional hopper systems using the same four criteria.

Applicability: Because a given plant may have many different automated assembly machines, each with slightly different operations and goals, a feed system for a given fastener should apply wherever that fastener is used. Each installation should be as uniform as possible to minimize maintenance and operational workload. Moveable parts (such as fastener magazines, if used) should fit in all relevant installations, while fixed parts (such as controllers or structures) should share similar components and characteristics with other similar systems.

Within a given fastener feed system, each component of the system must apply to as many potential fasteners as possible. For instance, a fastener magazine must accommodate as wide a range of fasteners as possible.

Due to the complexity of modern assembly equipment, the fastener feed system cannot be chosen without considering its impact on the rest of the machine. How it delivers a fastener to the tooling, and the impact on the system and support structure design must also be considered.

Reliability: High reliability is the major requirement for fastener feed systems. The enormous cost of the machines, combined with the high value of the parts being assembled, means that fastener misfeeds and their associated down time cannot be tolerated. For expensive or highly utilized machines, the major objective of the fastener feed system is to support machine up time. For less expensive or underutilized machines, a small decrease in reliability can be made in exchange for decreased system cost (first and/or recurring). When problems do occur, the recovery must be simple, preferably automated, and quick. Hard jams requiring equipment disassembly and non obvious or non detectable failure modes are highly undesirable.

Upgradability: Modern assembly machines do not operate in a static world: concurrent engineering, engineering changes, and model upgrades all mean that a fastener feed system installation must support enhancements and changes.

That means that the system must work with a broad range of fastener types and sizes, and must be chosen with support for future upgrades in mind.

Overall System Cost Effectiveness: The cost of a fastener feed system is not the purchase price. The extremely low purchase price of a drop tube system is soon negated if the cycle time on a multimillion dollar machine is slightly increased and the machine is unable to support desired production rates.

SMART HOPPERS

The smart hopper, shown in Figures 1 and 2, uses an integral proximity sensor and closed loop control to ensure that a fastener is always ready to supply to the installation tooling. The mechanical portion of the Smart Hopper shares

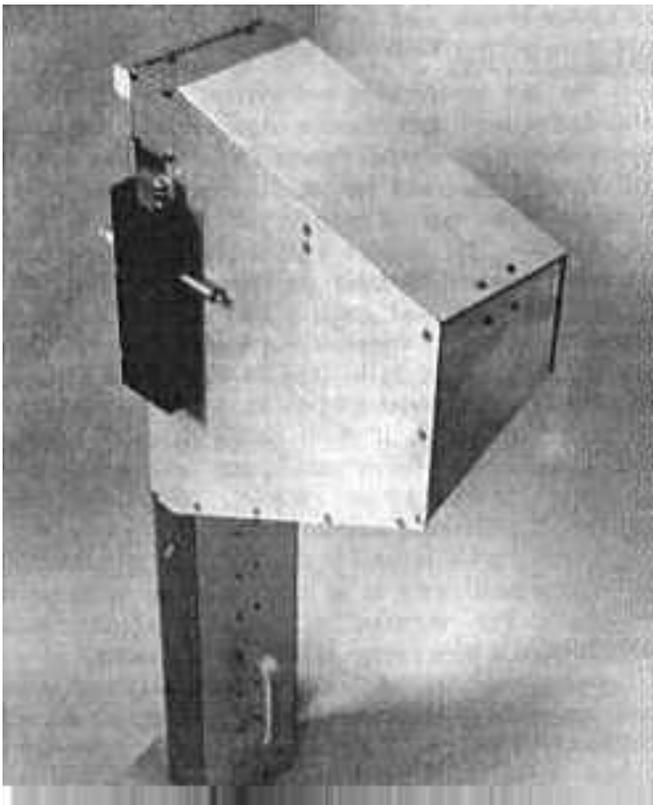


Figure 1. Smart Hopper

many similar components with the older technology, but significant modifications have been made to decrease the outside envelope while increasing performance.

The large **fastener bin (A)**, which holds bulk fasteners, makes up the entire front of the hopper.

The **reciprocating knife (B)**, which orients and separates the fasteners, has been mounted flush with the back plate of the hopper, allowing very long (up to 2.25") fasteners to be handled in a hopper 6 inches wide. Previous hopper designs, with the blade on the centerline of the fastener chamber, would have required an overall width of approximately 9" to handle these fasteners. For headed fasteners, the knife has a deep groove on top to allow the fasteners to hang from their heads. For slug rivets a shallow groove lays the fasteners on their sides in an end-to-end configuration.

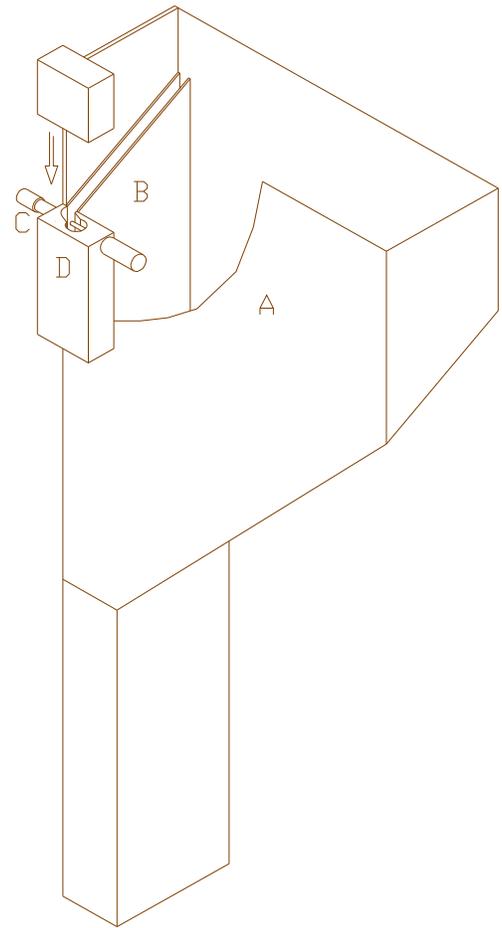


Figure 2. Smart Hopper

A "no-moving-parts" **escapement (D)**, (also shown in Figure 3) holds one headed fastener until that fastener is requested by the CNC, at which time the selected fastener is delivered to the tool point. The escapement actually has a piston which keeps the staged fastener from being dislodged by vibration or machine movement, but plays no part in moving the staged fastener. The escapement uses an entrained air stream to carry the fastener from the staging point, around a corner (insuring the fastener stays vertical), and down a feed tube. The escapement for slug rivets is described in the section on Coiled Tube Magazines (next).

A **sensor (C)** monitors the presence of a fastener within the escapement. Controls associated with the sensor are used to both start and stop the loading action of the knife and monitor whether the requested fastener was delivered.

The hopper blade moves on a linear ball slide, powered by a pneumatic cylinder. There are no sliding bearings within the bin of this hopper. An escape path is provided within the hopper for contaminants that find their way into the fastener bin.

All hoppers holding similar fasteners feed into a common feed tube through a system of gated passages (Figure 4). The passive gates deflect to allow a fastener to pass, yet the specialized geometries keep the cross section of the passage constant, preventing the fastener from tumbling. Hopper mounting on the structure, and tie-in to the passive gates, is modular to provide design and application flexibility.

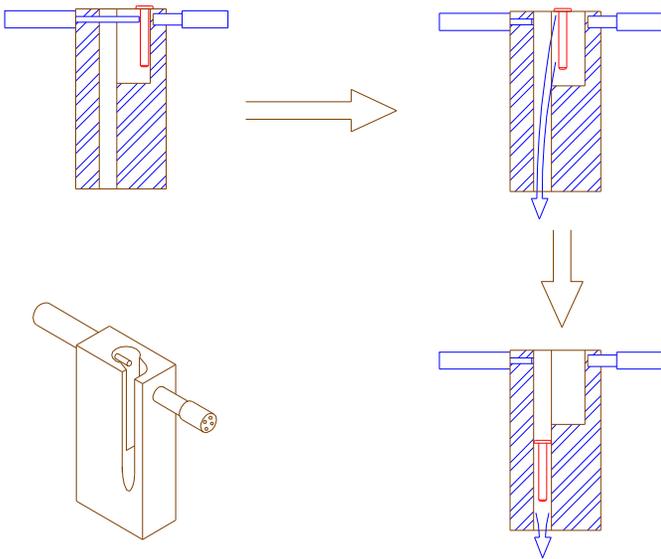


Figure 3. Hopper Escapement

Applicability: High. This system can handle any headed fastener or slug rivet, although it may have problems with very small ($\text{Ø}5/32''$ or smaller) aluminum fasteners due to limited sensor sensitivity. This system may be superior to others in size and complexity for very large fasteners.

Reliability: Medium. The closed loop computer controls make this system extremely reliable, with the added benefit of early fault detection. This system, like all on-line bulk feeding systems, is susceptible to debris in the hopper system from damaged fasteners, floor trash, or lubricant build up.

Upgradability: Medium. Modularized mounting and control systems make it easy to change an installed system from one fastener type to another. Often existing hoppers can be upgraded or changed to another fastener, or the entire hopper can be changed out.

Overall System Cost Effectiveness: Medium. On large installations (more than 20 hoppers), this system is very competitive with existing hopper technologies. On smaller systems the cost of the control system may make this option somewhat more expensive.

MAGAZINE BASED FASTENER FEED SYSTEM

The **coiled tubing** magazines (Figure 5) hold fasteners of

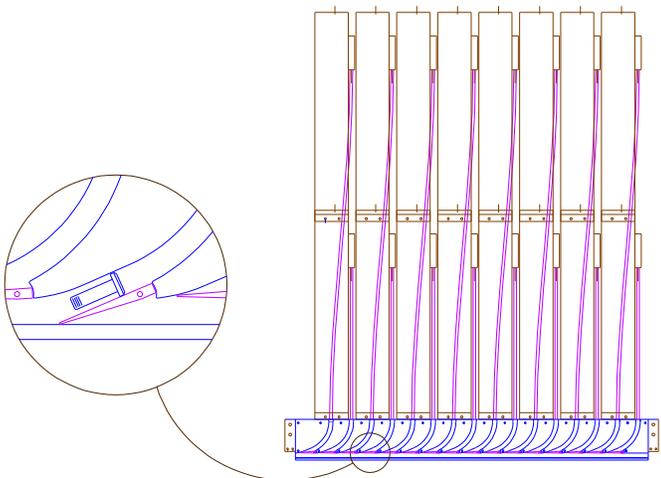


Figure 4. Gated Passages

almost any size or shape in an end-to-end configuration. Each magazine holds its own passive **escapement** within the magazine. Headed fasteners are escaped with a one-moving-part escapement, which works with all fasteners of a given shank diameter (Figure 6). Slug rivets are escaped with a one-moving-part escapement which is diameter specific but length independent (Figure 7).

All magazines which feed into a common feed tube mount on a common, multi station feed base. Once a fastener is escaped, coupled **rotaries** (Figure 8) change the orientation of the fastener and bring it into a common feed passage, then

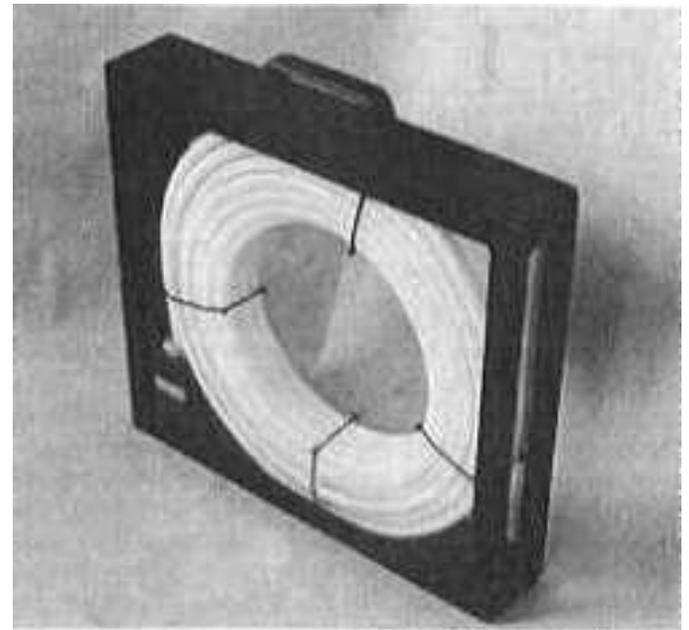


Figure 5. Coiled Tube Magazine (Cassette)

into the feed tube. The feed base with its rotaries makes for an extremely small installed volume, perfect for retrofits or large capacity new installations. The actuators for the magazine escapements are mounted within the feed base, so the magazines need only be put in place, not hooked up. The magazines are filled off-line, insuring that the problems of handling bulk fasteners do not compromise the uptime of the installed system.

Applicability: High. This system can be used on any fastener that can be stored or transported in a cylindrical tube. A given magazine may apply to many types of fasteners as long as they have identical or nearly identical shank diameters.

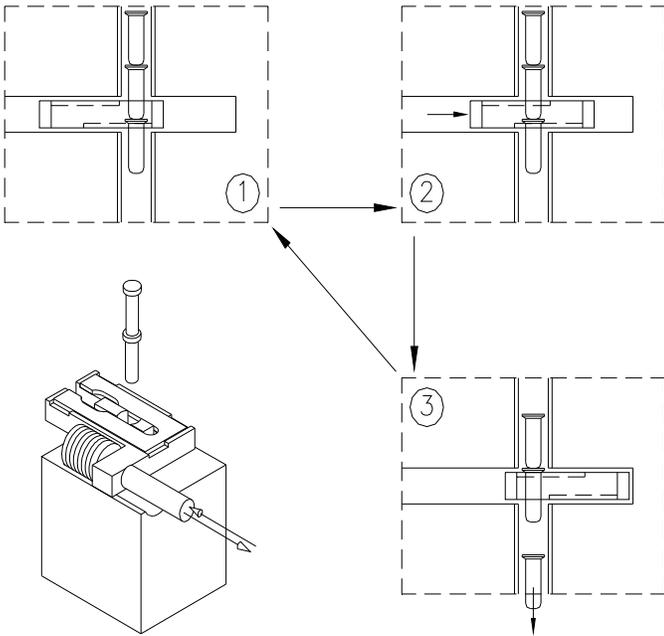


Figure 6. Headed Fastener Escapement

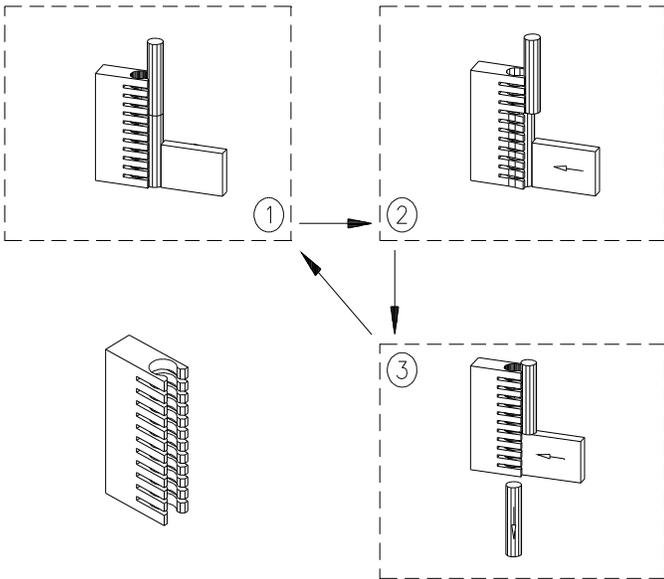


Figure 7. Slug Rivet Escapement

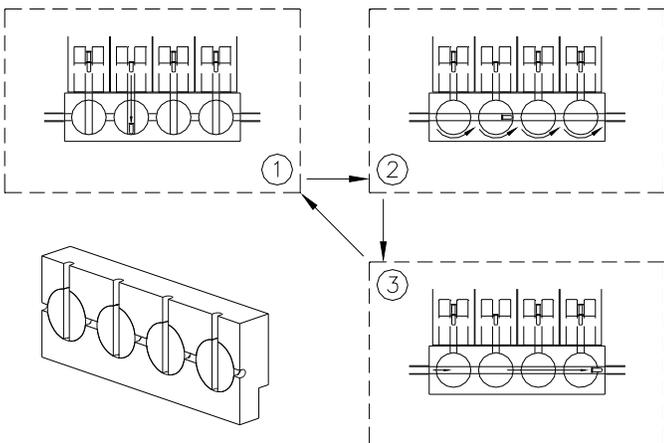


Figure 8. Rotaries

Reliability: High. The on-line feeding reliability of this system is outstanding. Unreliable bulk handling operations have been moved offline.

Upgradability: High. On common feed tubes, changing from one fastener to another only requires changing the magazine. Changing a magazine from one fastener to another often requires no modification, although at most the escapement will have to be modified or replaced.

Overall System Cost Effectiveness: Medium. The increased cost of the off-line filling system is more than paid for by the increased on-line reliability and simplicity.

SLUG RIVET MAGAZINE FEED SYSTEM

This elegant system uses simple components and motions to store, transport, and feed slug (cylindrical) rivets (see Figures 9 and 10). All similar diameter rivets are fed from **magazines (A)** mounted on the same **feeder base (B)**. **Escapements (C)** slide under the magazine to select the desired fastener, then slide back to transport the rivet to the common feed path. Rivets are loaded into the magazines off-line using a semi-automated rivet pump, which loads the rivets



Figure 9. Slug Rivet Feed System

into the magazine from the bottom to maintain orientation and order.

Slug rivets are loaded into magazines off-line and selected one-by-one for delivery to the installation cell. The rivets are loaded into the magazines side-by-side. **Latches (D)**, integral to the magazines, retain the rivets whenever the magazine is disconnected from the machine feeder base or the loader. The latch opens automatically whenever the magazine is installed.

Applicability: Medium. Slug rivets only, but different lengths can easily be accommodated.

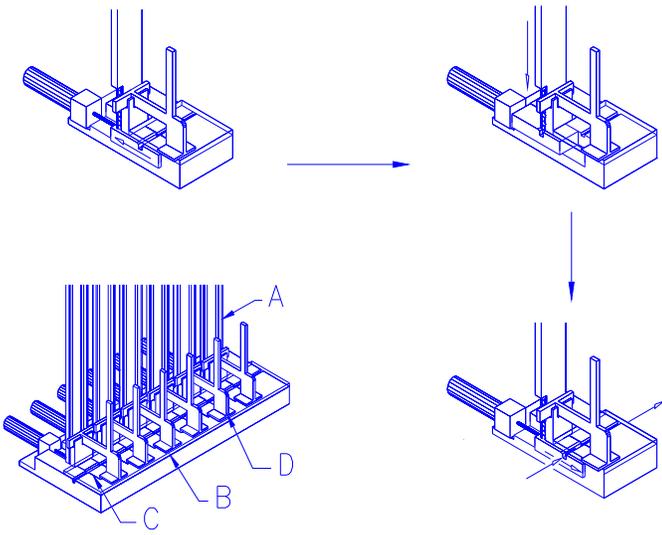


Figure 10. Slug Rivet Feed System

Reliability: High. On-line reliability is outstanding. Unreliable bulk handling operations have been moved off-line.

Upgradability: Low. The magazines, loaders, and feeder bases are specifically designed for a single diameter and small range of grip lengths of fasteners. The equipment cannot be used for other fasteners.

Overall System Cost Effectiveness: High, especially when the low installed size and weight of the on-line feed system and related support equipment are compared with traditional bowl feeders.

COLLAR AND NUT FEED SYSTEM

This system (the magazine and feed base are shown in Figure 11) uses a magazine based approach similar to the two

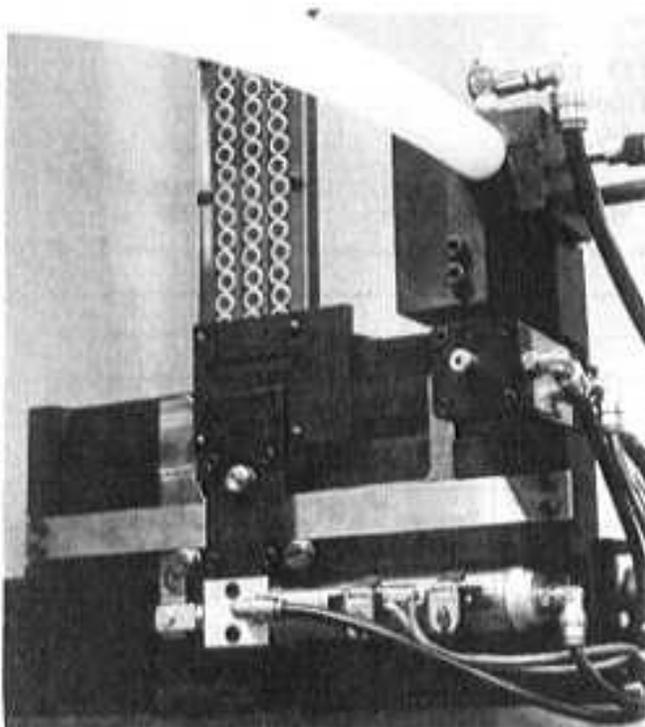


Figure 11. Collar and Nut Feed System

previous systems, but uses a dedicated part carrier to transport

the oddly shaped nuts and collars from the initial escapement pick point to an intermediate staging pin. The nut or collar is then transferred to the installation tooling in a separate operation. This system takes advantage of the well controlled center hole in these types of fasteners, ignoring the less controlled external geometry. It also allows the fastener magazine to be located well away from the installation tooling.

Nuts and/or lockbolt collars are loaded into dedicated **magazines** off-line in an edge-to-edge configuration. Each magazine contains its own dedicated passive **escapement**, which presents an escaped nut or collar on a common

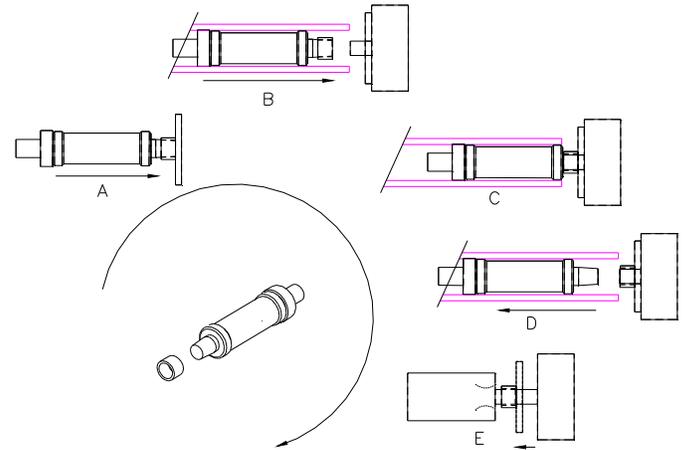


Figure 12. Collar and Nut Feed System

centerline.

A fastener specific carrier (called a **rabbit**) is inserted into the center hole of the fastener (Figure 12) (A), and then transferred up to a feed tube. The rabbit, with its associated nut or collar held onto a spring loaded pin, is then fed down to the tooling area where the nut or collar is transferred to a part specific **staging pin** (B & C). The now empty rabbit is sent back to the loading station (D), and the nut or collar installation tool (nut runner or swaging die), is then moved on to the staged part. A **stripper plate** transfers the nut or collar onto the end tooling of the installation tool (E).

Since the nut or the collar is handled by the center hole only except while in the magazine, the on-line tooling is greatly simplified. Fastener change-out is accomplished by changing the magazine and the rabbit. The staging device is merely shuttled to a different position to allow the fastener to be placed on its specific staging pin.

Another great advantage of this method is that the staging tooling is very small and light on the part of the machine where size and weight can be extremely critical.

Applicability: High. A wide range of fasteners can be accommodated by providing new magazines and rabbits, leaving the on-board equipment unchanged. New staging pins may or may not be required.

Reliability: Medium. The on-line system is very reliable, but the high number of activities in this difficult task can create problems. Unreliable bulk handling operations have been moved off-line.

Upgradability: High. By changing a very few machine parts many different fastener systems can be accommodated.

Overall System Cost Effectiveness: High. On multi-fastener machines this system is very cost effective, since most

of the equipment applies to many different fasteners. On single fastener (dedicated) installation machines this system may not compete economically.

BOWL FEEDERS

Traditional bowl feeders have many advantages: they are an understood, accepted technology; they are “accessible”, many service people are familiar with the technology and confident in the equipment; and, sometimes, bowl feeders are a low cost option.

For larger, more integrated systems, however, the low fastener motive forces (well under a fraction of the fastener weight) and high possibility for contamination make bowl feeders less attractive. Their relatively large size and high weight combine to increase the requirements on the platform design. Sophisticated sensor systems can decrease the occurrences of jams and mis-feeds, but these systems are poor substitutes for inherent reliability.

Applicability: High. Bowls can be tooled to handle almost any fastener..

Reliability: Low. The high potential for contamination and the low actuation forces available combine to make jams, misfeeds and wrong fasteners likely.

Upgradability: Low. It is often less expensive to buy new bowls than it is to re-tool.

Overall System Cost Effectiveness: Low. While bowl feeders are not particularly expensive, the large structural concerns and design overhead make the system cost high.

Like bowl feeders, traditional hoppers have many advantages: they are an understood, accepted technology; they are “accessible”, many service people are familiar with the technology and confident in the equipment; and, sometimes, they are also a low cost option.

They also share the same problems with bowl feeder systems: the low actuation forces (well under a fraction of the fastener weight) within the escapements and high possibility for contamination. The design also places sliding surfaces within the fastener bin itself, requiring adjustments for wear.

Applicability: Medium. Most fasteners of a given diameter will work within a hopper, with some adjustments required for air jets and clearances.

Reliability: Low. The high potential for contamination and the low actuation forces available within the escapements combine to make jams, misfeeds and wrong fasteners likely.

Upgradability: Low. It is often less expensive to buy new hoppers than it is to re-tool.

Overall System Cost Effectiveness: Medium. Hoppers are not particularly expensive and they are fairly lightweight for the fastener range and capability.

CONCLUSIONS

Figure 13 compares the systems presented with traditional hoppers and bowl feeders. The comparisons, by necessity, are very broad and may not apply in every instance.

It is apparent, however, that larger and more complex fastener installation machines require new approaches to fastener feed to maximize machine up-time, reliability, and increased process control.

TRADITIONAL HOPPERS

FIGURE 13
FEED SYSTEM EVALUATION/COMPARISON
 3=HIGH, 2=MEDIUM, 1=LOW

	SMART HOPPERS	COILED TUBING MAGAZINES	SLUG RIVET MAGAZINES	COLLAR AND NUT FEED SYSTEM	BOWL FEEDERS	TRADITIONAL HOPPERS
APPLICABILITY	3	3	2	3	3	2
RELIABILITY	2	3	3	2	1	1
UPGRADABILITY	2	3	1	3	1	1
SYSTEM COST EFFECTIVENESS	2	2	3	3	1	2
OVERALL GRADE	9	11	9	11	6	4
COMMENTS	Headed fasteners or slug rivets, active on-line controls. Susceptible to debris and mis-placed bulk fasteners.	Off-line filling station required, applies to headed and cylindrical fasteners.	Off-line filling station required, applies to cylindrical fasteners only.	Off-line filling station required, applies to many different fastener systems, staging pins must be designed into machine.	Very large and heavy, tooling is often very fastener specific. Susceptible to debris and mis-placed bulk fasteners.	Headed fasteners only. Susceptible to debris and miss-placed bulk fasteners.