Making the switch from manual to automated specimen handling

Robotics and smart conveying are streamlining specimen handling at one of the largest medical testing laboratories in the US, capable of storing 2.3 million samples and processing 4000 specimens per hour. Jim McMahon reports.

À l'heure actuelle, la robotique et la technologie de « smart conveying » (transport intelligent) simplifient la manipulation des échantillons dans l'un des plus grands laboratoires d'analyse médicale des États-Unis, capable de stocker 2,3 millions d'échantillons et d'en traiter 4000 par heure. Jim McMahon nous l'explique.

Roboter und intelligente Förderungstechniken, die 2,3 Millionen Proben speichern und 4000 Proben pro Stunde bearbeiten können, rationalisieren die Probenhandhabung in einem der größten Medizintestlaboratorien in den USA. Bericht von Jim McMahon.

ARUP Laboratories is not only one of the largest medical testing laboratories in the United States, it is also one of the most automated. Sporting the world's largest clinical laboratory freezer, 60ft x 30ft x 26ft in size, and operating at minus 20°C with a two-story automated storage and retrieval system (ASRS) that can hold up to 5220 stainless steel storage trays of specimens on indexed shelf locations, the system's capacity exceeds 2.3 million individual specimens. At the heart of the operation is a highly-automated sorting and transport system consisting of two robotic sorters designed by Motoman – which load and unload finished specimens into storage trays – and continuous-flow 'smart' conveyors built by Shuttleworth, which jointly retrieve and transport specimens for clinical testing in less than 2.5 minutes with a capacity of handling 4000 specimens per hour. For high-volume, efficient laboratory specimen handling, the system is truly a showpiece of precision automation.

But it was not always this way for Associated Regional and University Pathologists Inc (ARUP Laboratories, or ARUP), who for 20 years prior to automation was manually handling specimens. A national clinical and anatomic pathology reference laboratory and a wholly-owned enterprise of the University of Utah and its Department of Pathology, ARUP was created in 1984 by the University of Utah School of Medicine's Department of Pathology faculty to support its academic missions of education and research. ARUP supports the Department of Pathology by providing laboratory testing for the University of Utah Hospital and clinics while engaging in cutting-edge technology needed to establish ARUP as a leading national reference laboratory specialising in esoteric testing. ARUP has established itself as a role model for bridging the gap between academic medicine and successful business enterprise.

With 2500 employees, ARUP offers in excess of 2,000 tests and test combinations, ranging from routine screening tests to highly esoteric molecular and genetic assays. ARUP's clients include more than half of the nation's university teaching hospitals and children's hospitals, as well as multi-hospital groups, major commercial laboratories, group purchasing organisations, military and government facilities, and major clinics. In addition, ARUP is a worldwide leader in innovative laboratory research and development, led by the efforts of the ARUP Institute for Clinical and Experimental Pathology.

"Before automation, ARUP was using walk-in freezers at three different locations to store specimens," says George Falk, Project Specialist at ARUP's Central Support Services Group. "The samples were stored manually in cardboard trays, with a capacity of about 400 000 specimens. To find a sample, a tech had to go into the walk-in freezer with a box number (an X/Y reference) and search manually. Personnel were required to enter the freezer in pairs for safety reasons, wearing coats, when looking for a

Fig. 1. Smart conveyors into and out of the freezer utilise Slip-Torque, low back pressure accumulation to minimise sample damage.

specimen, a labour-intensive and time-consuming process."

This is still the case with many larger labs in the US – 40 to 50 per cent of these labs, those handling 15 000 to 20 000 samples per day, still utilise significant manual functions to store and route samples throughout their facilities, in addition to usually some form of semi-automation (small- to medium-sized labs use much less automation, if any at all). Laboratory automation for medical testing has typically been applied to centrifugation, aliquotting and the interfacing to analysers for serum chemistry, immunoassay, hematology and coagulation tests. For most labs 35 to 55 different tests comprise 80 per cent of their total workload. Because of ARUP's esoteric testing environment, more than 1000 different tests comprise 80 per cent of its test volume, many of these being infrequent manual tests performed in small batches, making its automation needs more demanding than that of other labs. Such needs included the elimination of excessive handling and sorting, improved tracking, storage and retrieval of specimens for repeat or additional testing, and real-time communication among all of ARUP's laboratory-related software systems.

ARUP developed a software system, ESP (Expert Specimen Processing), to facilitate rules-based automation of its specimen processing. The specimen accessioning process is performed in ESP, as well as automated storage of specimens and complete specimen tracking. The initial computer input of the specimen information is done in the doctor's office and assigned a barcode which is then logged into the ESP software. Even before the sample arrives at ARUP, all of the specimen's data is available as to where it is going and what needs to be done with it. ESP then tracks the specimen with laser scanning of the attached barcode throughout its entire lifecycle within the system.

To further optimise sample processing and tracking, ARUP adopted a 5mL standardised transfer tube which fits into the system's transport carriers and is tracked through ESP throughout the system. ESP and the standardised transfer tubes also facilitate use of the world's first automated thawing and mixing work cell. It thaws and mixes frozen specimens while in the transport system at a rate of more than 1,000 per hour, thus reducing pre-analytical preparation time. It allows specimens in the transfer tubes to be thawed in 30 to 40 minutes instead of the typical frozen urine samples requiring five to six hours to thaw when in 90cc bottles.

Critical to the ARUP system's success is its automated transport and sorting system which includes rapid transport to and from the specimen processing area and high-speed sorting into a large number of different sort groups. From even the most remote specimen processing workstation to the farthest sorter (there are two robotic sorters), travel time on the 1,100 linear-foot track is less than eight minutes.

"The continuous flow of specimens to the robotic sorters which are located near the laboratory area has eliminated considerable walking from the lab to where the specimens are processed," continues Falk. "Prior to the implementation of ARUP's automated track system, a typical specimen was manually sorted at least three times and handled seven to nine different times prior to testing."

High-speed, high-volume

Two sorting robots, AutoSorters built by Motoman, are attached to the automated track system. Optimised for high throughput, these robots automate the transfer of tubes from the automated track system into storage trays or racks for entry into the freezer for storage. Then when a sample needs to be recalled for testing, the AutoSorter receives the storage tray or rack from the freezer and retrieves the designated sample which is then conveyed out to the requesting lab tech. Both of these functions were previously a manual process. Trays are used to store tubes in storage categories of higher volume and racks are used for lower volume categories. A reader mounted on each of the robot's six grippers reads barcodes as the tubes are rotated by the robot, eliminating the need to otherwise orient the barcodes. Each sorter can sort up to 1100 tubes per hour into user-definable targets. The sorter in the refrigerator can sort into 39 target racks. The post-analytic sorters sort into eight user-definable targets for storage..

Controlled humidity

The AutoSorters are positioned within a large refrigerator (4°C) located at the front of the freezer, which serves as an anteroom to the freezer. When the automated doors to the freezer are opened to allow trays to go in or out, the environmentally controlled humidity of the refrigerator ensures that condensation does not form on the outside of the specimen tubes, which would inhibit reading the labels and barcodes on the sides of the tubes.

AutoSorter utilises advanced planar drive technology for the movement of tubes and racks/trays within the robot. Gears, belts and mechanical bearings are replaced with magnetic couplings and air bearings. One of the significant advantages of planar drive is the absence of friction and wear on the robot's four-axis motion components.

A PC-based control system is used to control the AutoSorter which communicates directly with the ESP to obtain specimen data, improving traceability and eliminating sorting errors. Similarly, sort results are passed back to ESP so full traceability of the specimen is known at all times.

Specimen trays entering into the refrigerator through the AutoSorter robot cells need to be precisely positioned for the robot grippers to contact the specimen tubes before releasing to the automated

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Fig. 2. A reader mounted on each of the robot's six grippers reads barcodes as the tubes are rotated into position.

storage and retrieval system in the freezer for archiving. Likewise, specimens exiting the freezer from the automated storage and retrieval system must again be precisely positioned to accommodate the exact placement of the AutoSorter robot grippers in the refrigerator before releasing to the laboratory. This is accomplished through a specialised system of continuous-motion input and output Shuttleworth conveyors.

The conveyors are roller conveyors that enable integrated devices allowing motion control of the specimen tubes. Product stops, pushers and clamps used to modify the flow of the tubes are all mounted below the surface which is critical because of the robotics moving above. If these devices were coming in from the side, such as what would be required on a belt conveyor, plastic link conveyor or a table-top chain conveyor, they would interfere with the robotic arms. They are also equipped with Slip-Torque technology which minimises sample damage by creating low back-pressure accumulation. Low line pressure throughout the continuous-motion accumulation conveyors allows for precise product placement with the AutoSorters. The conveyors can continue to take product flow from the upstream line for a period of time instead of stopping. A low-pressure accumulation buffer absorbs irregularities in the production flow, and provides a smooth, even flow on the line.

Slip-Torque utilises individually-powered rotating roller shafts and loose-fit rollers, which become the conveyor surface, powered by a continuous chain to control the drive force for the samples. The size and weight of the tubes determine the driving force and roller selection. When the samples stop on the surface of the conveyor, the segmented rollers beneath them also stop, generating low back-pressure accumulation, minimising sample damage.

The conveyor system utilises stationary roller shafts covered with loose segmented rollers which allow the same conveyor to be split into three independently-operating lanes. For example, the middle lane can accumulate, while at the same time the right lane and the left lane can both convey. Each lane can act independently, but is powered by only one motor, reducing energy costs.

The Shuttleworth system conveys and positions a master rack and a series of sample trays, the robotic cell then transfers specimens from the master rack to the various sample trays depending on what tests or diagnostics are to be preformed. The deck of the AutoSorter holds up to 39 racks. Specimen loading and unloading is managed by the continuous-flow conveyors, providing walk-a-way time sufficient to meet the needs of the lab. With an overall retrieval time of less than 2.5 minutes, the requested tubes are typically in a rack waiting for the employee when he or she arrives at the checkout station.

Showpiece lab

The automated handling system put in place for ARUP Laboratories presents a showpiece in high-volume and efficient specimen processing.

Such automation might only be economical for those labs handling high volumes of specimens daily, in the range of 15 000 to 20 000 samples. But those labs that do make the switch from manual practices to a highly-automated facility will not only experience a more efficient operation, but be in a better position to capture and hold market share into the future.

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