A Comparison Between Two Robotic Systems Used for the Production of Radiopharmaceuticals

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The importance of laboratory robotics for the routine synthesis of positron-emitting radiopharmaceuticals for P.E.T. has been demonstrated using a Zymate Laboratory Automation System (Zymark Corp.)(Brodack et al., 1988). However, the boom design of the Zymark robot wastes approximately 4.1 square feet of work space within the hot cell. This wasted space caused us to search for a more space efficient system, and led to the discovery of an articulate arm, manufactured by CRS and distributed in the United States by Hudson Robotics. The articulate arm not only solves the problem of wasted space but is also less expensive and has some technical advantage when compared to the Zymark arm.

Now that robotics has been proven to be a useful technique for producing radiopharmaceuticals, the next step in the evolutionary process is to reduce cost and maintenance of the system and lessen operator setup time, while still increasing efficiency and yield.

With the CRS arm, we are able to reduce cost by minimizing the size of the robotic hot cell. Within a ten square foot hot cell, the Zymark robot wastes a volume of space equivalent to 4.1 square feet times the height through which the robot will be operating. In comparison, the Hudson robot wastes very little space and can be mounted on the ceiling to allow for maximum use of work space. (Figure 1) The Zymark robot, however will waste the same amount of space regardless of its positioning, due to its boom design which requires a 4.1 square foot space for unrestricted operation.

To set up a system which will synthesize a variety of radiopharmaceuticals with a minimal amount of station redesign and operator intervention will require a work space of at least ten square feet. (Figure 2) To create this amount of work space for Zymark robot would require a 12 square foot increase in the hot cell workspace (assuming the hot cell isn't circular) , which would require twice as much lead, and would increase the cost and double the weight of the hot cell needed for synthesizing FDG and FES.

Comparing each system which includes the robotic arm and the stations it interacts with shows the Hudson System to be more flexible for developing a system that can use existing in house equipment and be easily modified. The CRS arm can be controlled by a variety of software packages supplied by CRS or other distributors of the arm. Therefore, the choice of software can be based on the user's computer, experience and needs.

The software supplied by Hudson robotics, TCS (Total Control Software) uses English based commands. For example, **the HERE <location name> command** is used to define the position of the robot. Then a series of **APPROACH <location names>, (number in inches)** and **DEPART (number in inches)** commands are used to move around the defined position. The **MOVETO <Location name> command** is then used to move to the actual position. All of the programming for the Hudson robot can be done from the programming screen using a teach pendant, allowing the user to move the robot, define the positions, then use any command and create programs simultaneously which is considerably less time consuming than the menu based programming of the Zymark robot.

Easylab, the programming language used for the Zymate robot uses a menu driven system which allows the programmer to move the robot and then define locations and motions to the location with symbolic words. The difference between the two systems occurs in the writing of the program. The English based commands of TCS eliminate the need for the motion definitions (relative positions) of Easylab. The menu driven system of Easylab makes it impossible to define positions, or move the robot and create a program without switching menus which is more time consuming than Hudson's method.

The computer architecture of the Zymate system limits the choice of stations to Zymark products. However, the CRS arm can be controlled by an IBM or IBM compatible PC which allows the integration into the system of any automated station that can be controlled through an RS-232 port. Total Control Software allows the use of original software for the station or the English based commands that Hudson has developed for that particular station.

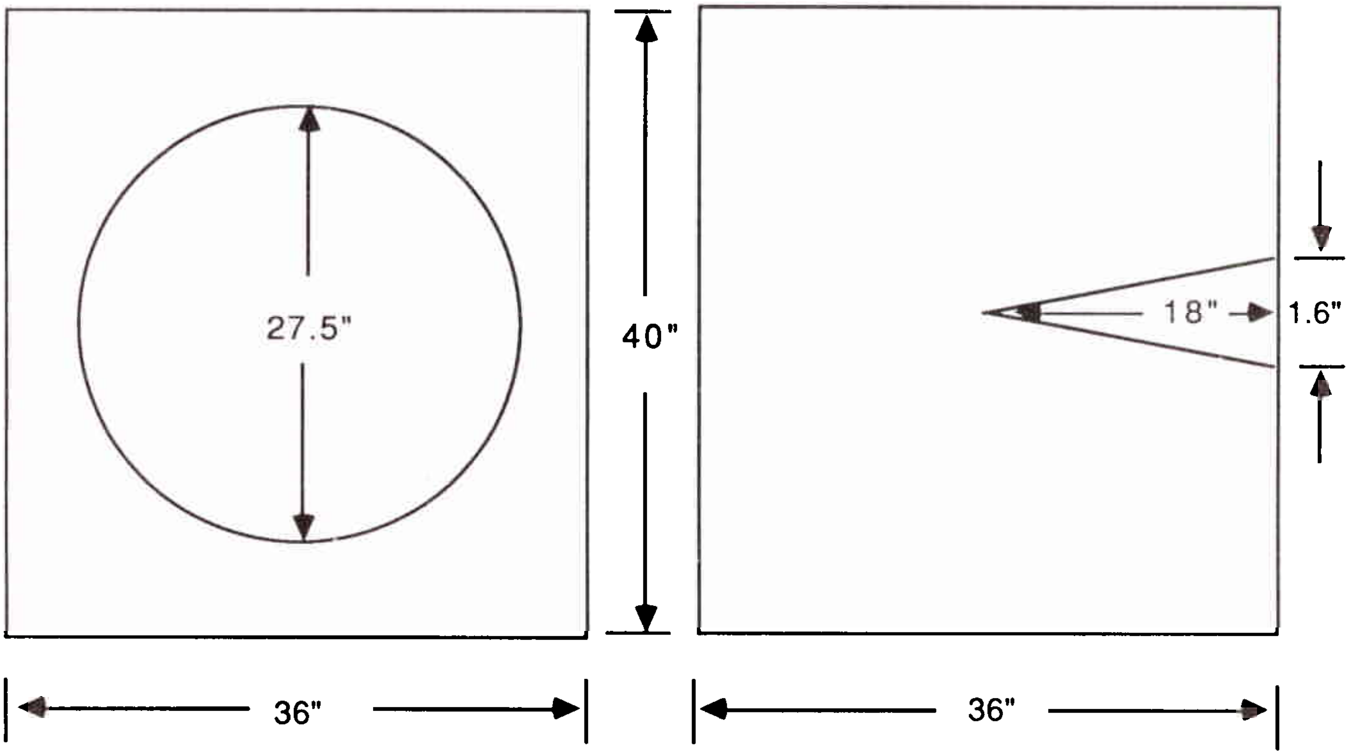
Hudson's software makes programming very simple, but sometimes, as in the case of HPLCs, the software provided for the HPLC gives greater control than Hudson's TCS. In comparison, the Zymate uses Easylab for all controls which makes it easy for a first time user to program but limits the capabilities of stations like the HPLC.

The added flexibility of the Hudson system can reduce cost by allowing the chemist to use the automated station they already have instead of purchasing a new one and by allowing the chemist to shop around for stations from other companies such as Hamilton, Cavro or Fisher. We have already encountered substantial savings by switching to the Hudson robot because the hot cell for the Zymark robot would cost nearly twice as much as the Hudson's.

The greatest advantage of the CRS arm results from its articulate movement. This gives it the flexibility to work in a crowded space by duplicating the motion of the human arm. The CRS arm also uses optical encoders to monitor its position which gives it a greater precision and requires less maintenance than the Zymark robot which uses potentiometers. The potentiometers in the Zymark robot slowly wear due to friction, leading to problems with drift and ultimately requiring replacement. This problem is eliminated with the use of optical encoders which are also less prone to interference. The performance comparison and maintenance list in figure 3 are based on manufacturer's specifications and recommendations. The list points out the performance characteristics of both robots and demonstrates CRS's greater precision and faster operation speed.

Robotic systems for the production of positron-emitting radiopharmaceuticals are proving to be a safe, reliable and flexible alternative to the remote and manual syntheses that are typically employed today. By increasing the variety and number of syntheses the robot can perform in a single day with a single setup, we will effectively be making the robot affordable in terms of chemists and operators time as well as reducing the space necessary to produce a variety of radiopharmaceticals.

Wasted Work Space Comparison



Zymark's Wasted Work Space

$A=\pi r^2$

$A=\pi(13.75)^2$

Wasted Area = 4.125 Sq. Ft

Hudson's Wasted Work Space

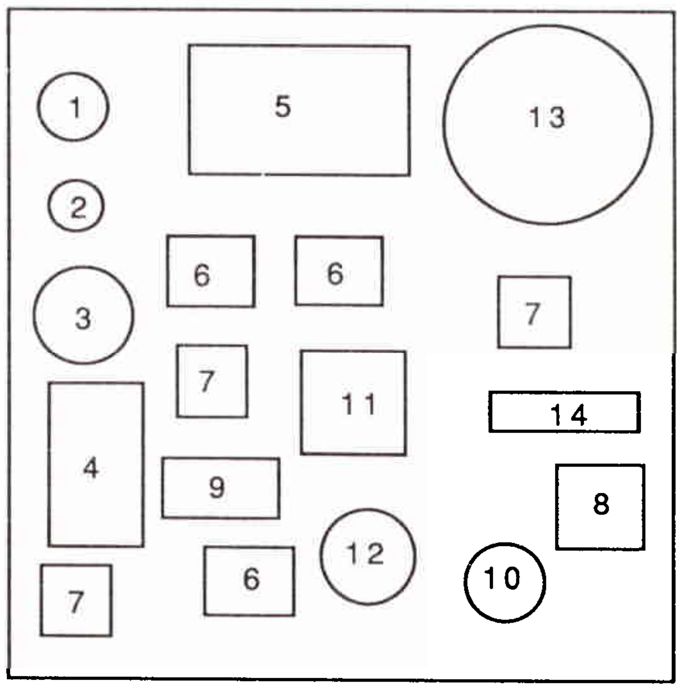
A=1/2hb

A=2[1/2(18)sin2.5(18)]

Wasted Area = .1 Sq.Ft

Figure 2

The diagram below illustrates the placement of station necessary to pref FDG and FES in a ten square feet area



Robotics Stations	Size sq.in	Robotic Statons	Size sq.in
1. Collection Pig	15.9	2. Product Pig	10.17
3. Doso Calibrator	24	4. HPLC Injector	52.25
5. Balance	94	6. Vessel Racks	20
7. Waste Bins	16	8. Vortex	25
9. Pipet Rack	23	10.Cooling Station	35
11.Heating Station	32	12.Capping Station	24
13.Fraction Collection	113	14.Liquid Extraction	12

FIGURE 3

Performance and Maintenance Comparison

Comparison

	Hudson		Zymark	
Repeatability	+/- 0.005		+/- 0.05	
Payload	4.4 lbs (80% speed)		3 lbs	
Speed	Joint		Axis	
	Base	100°/sec	Rotation	70°/sec
	Shoulder	62°/sec	reach	6.3 in/sec
	Elbow	100°/sec	Vertical	4.3 in/sec
	Wrist	180°/sec	Wrist	-
	Tool	360°/sec		

Maintenance

Hudson	Time	Zymark	Time
Transmission chains	1000 hrs	Transmission Cables	Monthly
Check Wiring Harness	1000 hrs	Check and clean arm	Monthly
Check Arm Covers	2000 hrs	Check Motor Current	Quarterly
Check Motor Brushes	5000 hrs		
Clean and Refit Harmonic drives	8000 hrs		

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