4. Scheduling and optimizing of radionuclide production

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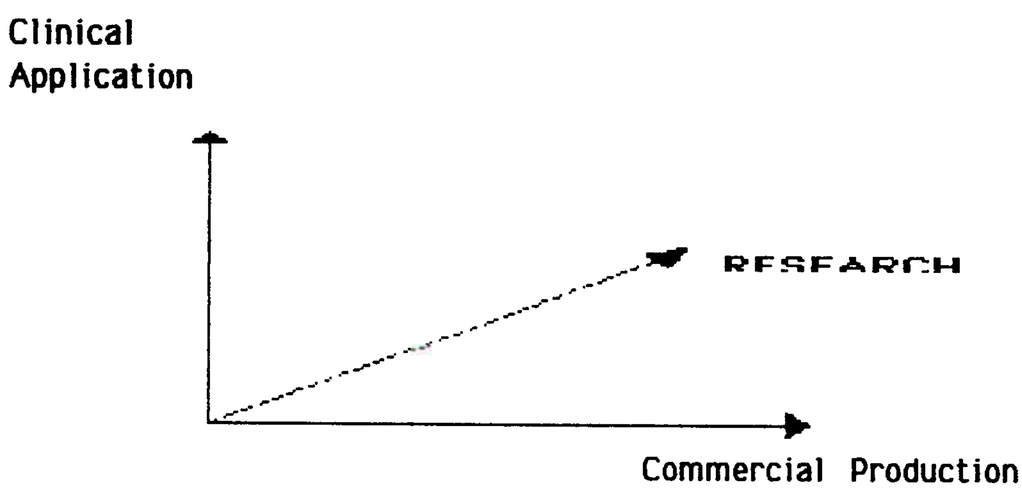
The goal of all optimization procedures can simply be defined as to set the production parameters in such a way that all beam users are satisfied to the greatest possible extent.

Since cyclotrons which are used as tools in life-sciences may have very different tasks and may be located in various environments the definition of optimal production setting is difficult and dependent upon the purpose of its operation.

Therefore it seems necessary to define the goal of the cyclotron operation and to define the production goal before outlining the optimization task. In order to do this one should ask for:

- the main purpose for cyclotron operation
- the environment of cyclotron operation
- the type and specific capabilities of the cyclotron
- the cost-efficiency pressure to be taken into account

Using a three dimensional array of task directions one would have to define ones status, in order to make the optimization goals of a specific cyclotron understandable for other cyclotron operators and users.



Figure

In a research oriented environment the flexibility of the system and the goal of performing at the maximum capability in terms of energy and current would be more desirable than absolute performance stability, easy service access and fully automated production, which, however, would be considered of greatest importance for a

References

1. Y. Jongen, "Conceptual Design for a High Intensity (5 mA) Industrial Cyclotron", in Proceedings of 10^{th} Int. Conf. on Cyclotrons, East Lansing, May 1984 of IEEE 84CH1996–3, pp. 465–468.
2. W.K. van Asselt, O.C. Dermois et al., in Proceedings of 9th Int. Conf. on Cyclotrons, Caen, sept. 1981, pp. 267–272.
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commercially operated cyclotron. In a clinical environment, the main goal for optimization could be defined as a compromise of performance reliability, simplicity of service, and flexibility.

In many cases the cyclotron which is available for the intended purpose will not be the ideal machine. This necessitates additional compromises in setting up the optimum performance parameters. For instance some users have to make use of high energy physics cyclotrons or injector cyclotrons for radionuclide production, while others still have to work with low energy linear accelerators or tandem van de Graaff accelerators. In both cases very special operation conditions and precautions will have to be considered for radionuclide production.

After these introductory remarks the possibilities of tuning a given cyclotron in a given environment to optimum performance shall be looked at. The single topics could then be discussed in detail.

<u>Hardware considerations:</u>

– automatic (computer driven) cyclotron operation	good? no good? to what extent?
– robotic service installations	necessary?
– multiple beam lines	how many?
– automatic target changing devices	linear sleds? or circular? others?
– parasitic beam use	tandem targets? line sweep? examples?

<u>Organizational considerations</u>

– service schedule	fixed and/or flexible? experiences?
– production schedule	fixed or flexible? to what extent?
– defining priorities	target and machine considerations vs clinical application demands.
– scheduling to minimize machine wear	efficiency? operator dependent? operation costs vs flexibility?
– coordination of particle sequence and/or energy and frequency sequence of subsequent runs	necessary or useful?

<u>Target chemistry considerations</u>

– Target gas changing	to be avoided totally?
– Operation at maximum yield (stress) conditions	necessary? use of safety margin in terms of current and density (pressure) desirable?
– reduction of radiation dose to service personel	experiences?
– cost – efficiency relationship	any considerations currently existent?

Most of the questions put here can not be answered unambiguosly. Again the answers will be very much dependent from the standpoint within the three dimensional task array and the hardware which is available. Nevertheless the questions are intended to help to find ones standpoint and to make the proper decisions when trying to optimize a given set-up or to optimize the configuration for a certain goal.

In order to realize the difficulty with optimatization procedures two examples of unnecessary attempts of the bivalency of such attempts are given:

1) Optimation of the target performance in terms of maximizing the extraction of a nuclide in a certain precursor form for clinical applications is not necessary, if the production goal can be reached with a target, which, despite lower yield, can be serviced better and which may even consist of an Aluminum target body which does not get as hot as an SS body. See e.g. discussion on ^{81}Rb production and even ^{11}C production.

2) Optimizing the specific activity in a production process in terms of target size, gas purity and analytical control efforts is useless, unless the carrier dilution in following chemical steps is not strictly controlled and minimized to such an extent that the efforts are really worthwhile. For instance any efforts to increase the specific activity of $^{11}CO_2$ is useless if the next chemical step is a Grignard reaction or a reduction with $LiAlH_4$ since both reactions usually introduce amounts of carrier which are orders of magnitude higher than the CO_2-contamination in the target gas.

Discussion

Following these comments P. Strudler made some remarks on the PET concept and the design considerations for the NIH PET center. He especially outlined the reasons which lead to the installation of two cyclotrons, emphasizing the operation capabilities and the possibility of splitting the tasks for research oriented work and clinical applications.

D.J. Sylvester and J. Clark mentioned the difficulties which may arise from sharing the cyclotron for radionuclide production with physics and neutron therapy applications. The time schedule usually gets though enough without the obligation to share the beam-time with other users.

The most annoying downtime is for unexpected service on the machine and targets and this time could be minimized by installation of good and flexible shielding for service personell.

For regular optimal beam use the scheduling has to consider the chemistry preparation times in front of the irradiation, as well as after EOB. This means that bombardments for subsequent application runs must be interlaced in sequences which are coordinated with the chemistry procedures. For instance in an application using ^{15}O, ^{11}C and ^{18}F radiopharmaceuticals in this sequence the irradiation sequence would most likely be reversed.

It was pointed out that an intercom/display system could be very useful in order to keep the whole group from physics to physicians informed, however, that the coordination of the system requires a strong and acknowledged person.

There was an agreement among the participants that the priority of clinical application runs should be the highest, followed by animal and biological application runs. However, a high amount of flexibility is necessary to keep a strong clinical program going.