AT8900234

ATOMINSTITUT
DER ÖSTERREICHISCHEN UNIVERSITÄTEN

PNEUMATIC TRANSFER SYSTEMS

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AIAU 88308

Nov. 1988

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INIS-KEYWORDS :

PNEUMATIC TRANSPORT
IRRADIATION DEVICES
RESEARCH REACTORS
REACTOR EXPERIMENTAL FACILITIES
LABORATORY EQUIPMENT
SAMPLE CHANGERS
NEUTRON ACTIVATION ANALYSIS

SUBJECT CATEGORY: E 15

CONTENTS

1. General Requirements of a Pneumatic Transfer System for Irradiation Facilities.

Facilities for sample irradiation, like large isotopic neutron sources, research reactors, neutron generators, gamma irradiation sources, in most cases require remote handling systems for sample transport to and from the irradiation position. Especially for facilities where the irradiation sources cannot be switched off or removed to a safe shielding position, such transport systems are essential.

At neutron emitting radiation sources the irradiated material is becoming radioactive during the irradiation procedure and this radioactive samples have to be transported from the irradiation position to a terminal for processing or measurement. If such a transport system is installed in the core of a nuclear reactor, this system has to be of utmost reliability. Properties of construction materials, design and manufacturing have to be of the very best. Due to the handling of radioactive samples, health physics considerations and contamination problems have also to be taken into account. Computer aided operation of the whole system nowadays is state of the art for such transport systems and many special requirements have to be met additionally to tailor the whole system to the demands of the relevant user.

In the following some details of a pneumatic sample transport system for reactor irradiation are described.

Pneumatic transfer systems for irradiation experiments in a research reactor are either used for isotope production or much more frequently for neutron activation analysis. Neutron activation analysis can be carried out as a purely instrumental method with little time consumption, high degree of automation, and without chemical treatment of the sample to be analyzed. Therefore, where research reactors are available, this analysis technique is increasingly applied nowadays to achieve a better and more economic use of an operating research reactor facility.

Irradiation periods of some minutes or even shorter for the activation and subsequent radioassay of short lived radionuclides are used. Qualitative and quantitative analyses for elements like Na, Mg, Al, Cl, K, Ca, Ti, V, Mn, Cu, Br, Ba, some rare earth elements, and U can be done within a few minutes. With special high speed pneumatic transfer systems neutron activation analysis of some 20 elements can even be carried out within a few seconds. If a sample transfer system at a research reactor is used for neutron activation analysis, many transport cycles have usually to be carried out during one working day. During this type of work samples will be transported from a loading terminal to an irradiation position and back to a detector terminal for immediate measurement or for radioassay after a short decay period. In addition, samples may be activated in the reactor for a longer period and after irradiation, they are stored for a while before measurement. So the samples after irradiation have first to be transported to a storage position (i.e. a delay stacker).

Design and construction of a pneumatic transfer system for neutron activation analysis have to meet all these above mentioned requirements for transfer capabilities. Therefore sophisticated pneumatic transfer systems involve automatic sample loading terminals where a number of samples can be inserted, waiting for transport to an irradiation position. One or sometimes more irradiation positions are provided in the reactor core (e.g. low flux, high flux, and epithermal neutron irradiation positions). From the irradiation position the sample is either transferred to a storage or to a measurement terminal. For such sophisticated and complicated systems, transfer switches have to be provided, to change transfer pathways of the samples as required.

The costs of multi-switch transfer systems are rather high, therefore the customers usually try to cut down the number of switches to a reasonable minimum.

A pneumatic transfer system to be installed in a reactor and meeting modern state of the art requirements will always use a closed loop and filtered air system. By this system, no radioactive aerosols and no argon-41 will be released at the loading and unloading terminals into the laboratory environment. In addition, if both, overpressure to push the sample and underpressure to drag the sample, are used in the transfer tube, the transport speed can be increased drastically. At old-fashioned systems a very high overpressure has to be applied to reach such a transport speed and after arrival at the terminal a great amount of air containing radioactive materials is released at conventional systems.

A transport system based on a good design also reverts the pressure adjustment just before the arrival of the sample at the terminals in order to achieve a "soft landing" at the relevant terminal. By that there is practically no danger that the transport vial can be broken and radioactive sample material can be released into the transfer tubing system. This extremely valuable operation detail is achieved by installing light beam switches at relevant positions in the tubing system. By these switches the air pressure is properly regulated.

It is very advantageous, if the transport tubing is made of plastic material, providing the opportunity to change the transfer route and transfer distance as required in case terminals have to be moved to another laboratory. Using plastic tubings, installation can be done with minimum trouble for the customer.

Due to the computerized system, all experimental parameters for irradiation time, storage period, etc. can be set easily and precisely without mechanical adjustments. Mechanic relay systems, mechanic stop watches etc. should be avoided nowadays and electronic devices of the present state of the art have to be used.

It should not be necessary to mention that exchange of filters, cleaning of pressure containers and other routine service work has to put the least possible burden on the customer. Routine service has to be as simple and easy as possible.

A collection of spare parts should ensure a smooth operation of the system for many years without interruption caused by waiting periods for missing items.

In addition, especially customers in developing countries will enjoy a complete set of tools to install and service the whole equipment.

2. Description of a Pneumatic Transfer System for Research Reactor Utilization.

In the following chapter a rather sophisticated but very versatile Pneumatic Transfer System will be presented which has been designed, constructed and installed by the Atominstitut of the Austrian Universitities. This system incorporates all requirements of a modern design as described above and fulfills todays needs both for neutron activation analysis and for isotope production The major advantages are listed below:

- closed loop system with practically no air release,
- sample transfer by over- and underpressure,
- large sample storage capacity at the loading station,
- delay stacker for decay of short lived nuclides before counting if necessary,
- two irradiation and two detector terminals,
- two drop out stations.

Especially the closed loop design is very important from health physics aspects as there is

- no argon-41 release out of the system,
- the sample is released from the system without overpressure,
- underpressure increases the sample transfer speed,
- during the sample transfer only minor air volumes are involved (the system works without blower).

An overall diagram of this system is shown in fig. 1.

The polyethylene sample container (dimensions 50 x 16 mm) is loaded at the capsule loader (CL) and is then transferred by slight overpressure into the loader stacker (LS) which is designed to accept up to 200 sample containers in case of automatic operation. From the loader stacker the sample can be transferred through the diverters D4 and D2 to diverter D1 which deviates the sample either in irradiation terminal IT 1 or IT 2. These in-core irradiation positions are preselected before starting the system; more than one in core irradiation positions are possible.

After the preset irradiation time has elapsed the irradiation sample will now be transferred to different destinations which are either

- directly to one of the two detector terminals (DT 1 or DT 2) where high resolution gamma spectroscopy detectors can be installed

- through a delay stacker (DS) with preset delay time to one of the two detector terminals

- directly to the drop out station (DO 1), if the system is used for isotope production or if the sample will be analyzed in a location other than DT 1 or DT 2.

From the detector terminals DT 1 or DT 2 triggered by the gamma spectroscopy system or manually the sample is finally transferred to the drop out station DO 2 for further disposal or reuse.

Along the sample pathways photo detectors (PH_i) are installed to give the operator an up to date information on the sample present location as well as to support the control unit with accurate information.

The central compressor station delivers the necessary over - and underpressure distributed by a set of magnetic valves. The compressor station is equipped with an oil free piston compressor (capacity 4 l/min). A volume of 40 l overpressure at 2,5 bar and 200 l of underpressure at -0,5 bar guarantee the sample transfer over distances up to 80 m with a velocity of about 10 m/s. Utmost care has been put into the design to reduce any loss of air from the whole system. In the present case the samples are transferred through a 3/4" polyethylene tube, only the part installed in the reactor tank is made of metal (stainless steel or aluminium).

The high flexibility of the system is obtained by using standardized diverters (DV_i). These diverters are mounted on bifurcations to direct the samples to the desired terminals (see DV 1,2,3,4,5,6,7). A diverter basically consists of a metal structure with a linear motor driven sledge, whose position is controlled by microswitches. While the main part of the diverter has two connections to the transfer tube, the sledge is connected to one moveable tube which may be aligned with either of the two tubes by moving the position.of the sledge.

Another group of diverters (CL, LS, DS, DO 1, DO2,) work on the same principle, but are of a modified construction. These diverters house photodetectors (PH) which detect the presence of a sample. They are used in the loading-, delay-, and drop out system to assure the closed loop design. If the presence of a sample is detected, the diverter sledge controlled by the programmable control unit moves from one position to the other (i.e. from "b" to "a" in fig. 1), then the respective magnetic valves are triggered to move the sample away. The time the valves are opened is optimized during system installation as this depends on the tube length. In the drop out system the sample arrives at the closed diverter (no contaminated air release), then the sledge moves to the other position and the sample is released only by gravity to the drop out container.

The Pneumatic Transfer System is controlled by a programmable control unit. In the present case the control unit accepts 1600 commands which is enough to handle all experimental requirements. Besides this control unit an operator panel exists near the capsule loader (CL) where the operator presets the sample pathway, selects the irradiation.- and if necessary - the delay time and starts the system. For further use a personal computer (like an IBM PC) can be connected to the control unit.

The preprogrammed control unit moves the diverters into the requested position, checks the arrival or passage of the sample through photosensors and actuates in proper time sequence the magnetic valves.

In addition to the various pathways the possibility of a reset- and sample blow out programme is provided to purge and to reset the system before experimental use if necessary.

The system is designed in a modular form for easy mounting, dismantling, cleaning and rearrangement. As the tubes are connected to the diverters by standard screw cap locks with rubber O-ring seals they can be opened easily, inspected and reinstalled. In case of contamination the system can be cleaned by standard detergents and clean water. All dust particles, iodine, humidity etc. are collected in double filters before the compressor.

3. General Requirements for pneumatic sample changer systems.

Usually high resolution gamma spectroscopy equipments are tools by which most valuable, necessary and useful data can be provided in nuclear research and routine radioassay work. In addition, an enormous amount of these data is obtained if the instrumentation can be used efficiently and if a reasonable status of automation can be provided to have that precious equipment operating around the clock without unnecessary and useless standby periods.

Especially in nuclear analytical work e.g. in activation analysis applications, a great number of samples has to be measured by gamma spectroscopy. An automatic sample changing system combined with a computer aided gamma spectroscopy facility is imperative for efficient work at an up to date level. Before choosing a suitable sample changing system one has to consider carefully the requirements to obtain accurate, precise, and reproducible results from a great number of radioactive samples at economic conditions regarding investment and maintenance.

A sample changing system for samples emitting gamma radiation cannot be constructed following the usual design for beta counters or for liquid scintillation counters.

If a large number of samples is stored in the vicinity of the detector, there is little chance to obtain accurate data for low background measurements. Either an enormous shielding has to be provided or sample storage and sample counting positions have to be installed at a suitable distance from each other. Preferably a storage terminal and a counting terminal are set up in different rooms. The samples can be prepared in a radiochemical laboratory under the necessary health physics requirements. The storage terminal may be in the same area. From there one sample after the other is sent to the counting terminal, stays there for a predetermined time and after counting the sample is sent back to another storage container in the laboratory. Using such a design, there are no problems with increased background radiation levels in the counting room.

To achieve this aim, a suitable transport mechanism for samples has to be provided between storage terminal and measurement terminal. The transport mechanism can be operated by a pneumatic or mechanic system. A pneumatic transfer system has some important advantages: The transport pathway and distance can be adjusted most easily according to the conditions of the relevant research laboratory and the counting room. A plastic tubing system connects storage terminal and measurement terminal. Any changes can be done with the least amount of financial investment and work. The system is perfectly flexible. Measurement geometry at the counting position can be changed without problems, just by adjusting the measurement terminal at the desired position and distance from the detector. Any three dimensional adjustment can be performed within a short time.

The transfer speed of a pneumatic system is much faster than that of a mechanical one. This is not a very important detail, but during many hundreds of sample transport and measurements cycles this property helps to save time and to use the counting equipment more economically and efficiently.

A pneumatic system is much more economical than a mechanical one. Design, construction, installation, and maintenance costs of mechanic systems are much higher. Only if it is necessary to handle spacious samples like large MARINELLI beakers or samples of more than 100 gram, a mechanic system with clamps and elevators is the better choice.

It is just state of the art that any system is operated from a personal computer. It might be a good idea to include a multi channel analyzer chart and suitable software for peak search, nuclide identification etc. in the PC programme packages. There are many multichannel analyzer charts for PC systems available on the market nowadays, their quality of design and performance should not be discussed here, it has only to be mentioned that software packages of multi channel analyzer systems and sample transfer systems have to match each other to avoid endless troubles for the user of the equipment.

Tailor made programs for sample transfer and measurement time, to add a header for information about sample origin, type and mass to the file, options for peak search and peak evaluation, for nuclide identification and if necessary also for neutron activation data calculation using standard or K_0 - methods, are extremely helpful for nuclear analysis work.

Supply with pressurized air for the pneumatic system can be taken from an already available laboratory pressurized air system or a small compressor can be supplied by the manufacturer to be independent from unreliable pressure conditions.

Pneumatic transfer systems can be designed and constructed nowadays to meet requirements of utmost reliability and also to facilitate routine maintenance work. The terminals of outstanding high level designs are made of transparent materials, like perspex. Nothing is hidden and that type of sample transfer system operates at the highest level of "transparency".

4. Description of a sample changer system (see fig. 2).

Samples for neutron activation analysis are normally welded into quartz glass tubes or, for short activation times, into polyethylene capsules. Therefore sample containers are rarely guaranteed to be of exactly the same size. This possible source of error was eliminated by using standardized transport containers, large enough to hold any of the various types of sample vials.

Transport containers 17 mm in diameter and 60 mm in length proved most suitable for the great majority of samples. The sample magazine is designed to store up to 25 samples. Optionally there are storages up to 50 samples.

The sample changing and pressurized air control mechanisms are combined in such a way that the sample loading cylinder also acts as a piston for pressurized air control The simplicity of this arrangement guarantees easy handling and a long working life. The pressurized air (up to 5 bar) is controlled by a simple magnetic valve. The transportation time can be adjusted to the length of the path (up to 20 m) and the sample weight by computer or any other electric controller.

The transport tube is made of polyamide and allows a bending radius of less than one meter.

The transport velocity depends on the air pressure, the sample weight, and on the vertical level distance of the terminals. For horizontal transport with a sample weight of one gramm, the velocity is sbout 2.5 m/s.

The detector terminal is made from acrylic glass, easily to be mounted at the detector. Also tailormade parts for a special detector geometry are available.

Acrylic glass is used, as it enables inspection of the operation and because of its high chemical purity., which is the reason why there is only minimal back-scattering in the measuring position.

If the registration and evaluation of the gamma-spectra are performed by a personal computer, the pressurized air valve is operated by a time controlled current pulse generated by a computer controlled relais. The programme for the valve operation also enables the control of the gamma-spectroscopy system. Nowadays many systems are also equipped with a sample changer start bit and busy signal acception.

5. Summary.

The described sy^‘ems are presently available on a commercial basis from the Atominstitute, the delivery times and the price depend on the specific design. For any further information contact any of the authors.

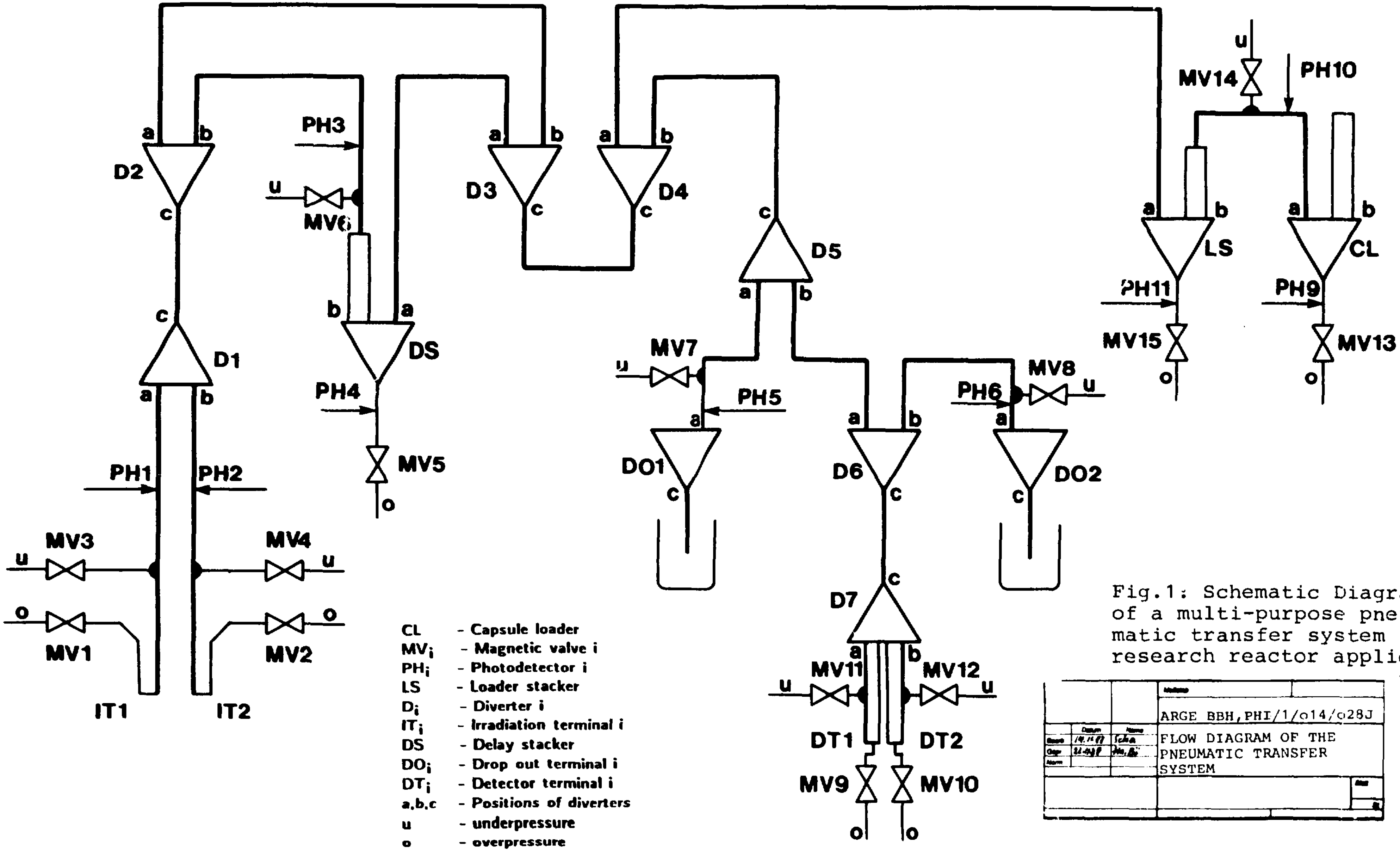

Fig.1: Schematic Diagram of a multi-purpose pneumatic transfer system for research reactor application

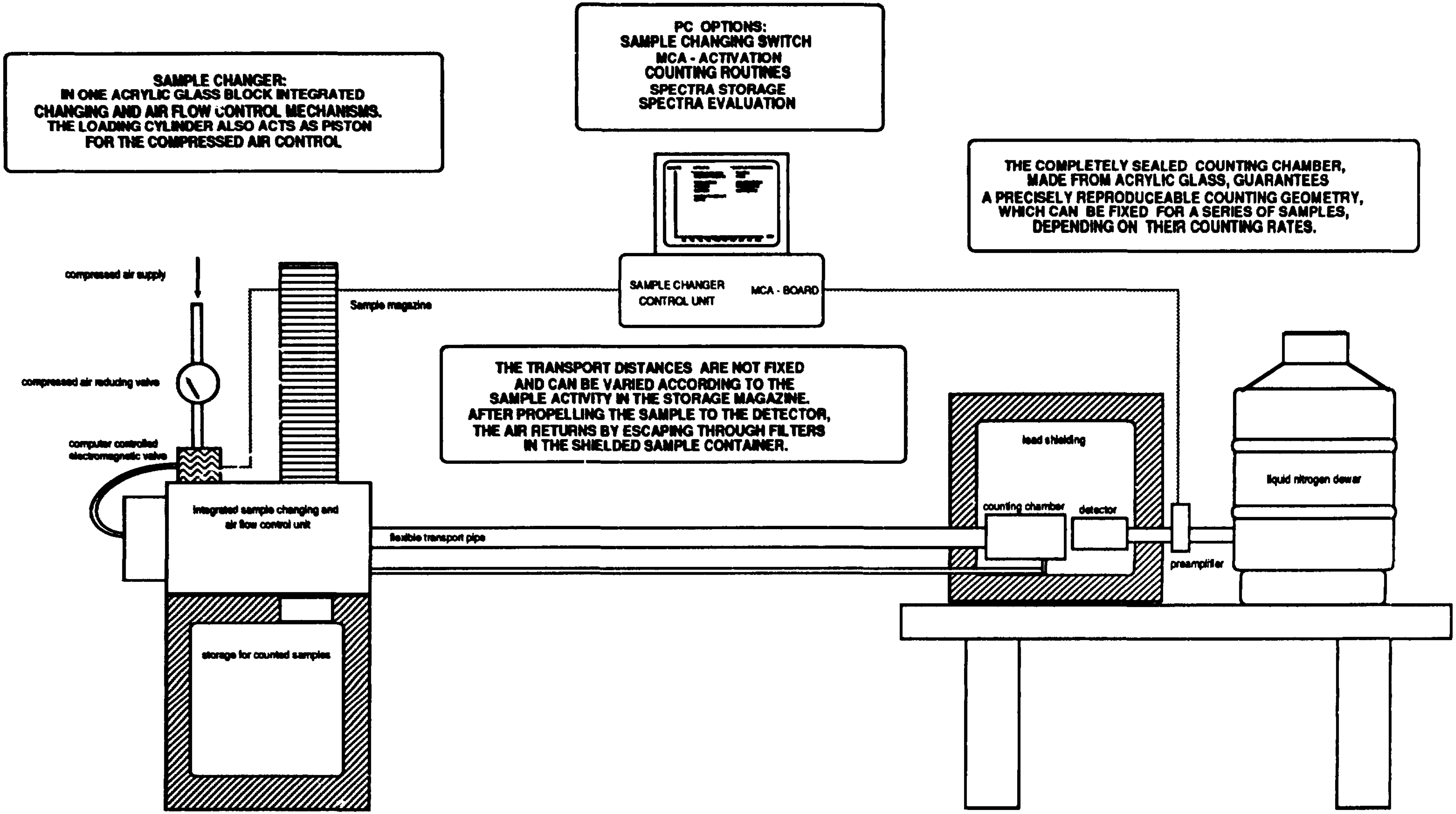

Fig. 2: Fully automatized NAA - sample changer system

AIAU-Berichte
Eigentümer, Herausgeber, Verleger und Druck:
Atominstitut der Österreichischen Universitäten
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