AUTOMATIC SAMPLING OF RADIOACTIVE LIQUORS

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ABSTRACT

This paper describes the latest techniques in sampling radioactive liquors in an Irradiated Fuel Reprocessing Plant. Previously to obtain a sample from these liquors operators were involved at the point of sampling, the transport of samples in shielded containers to the laboratories and at the offloading of the samples at the laboratory. Penetration of the radioactive containments occurred at the sampling point and again in the laboratory, these operations could lead to possible radioactive contamination. The latest design consists of a Sample Bottle Despatch Facility Autosampler units, Pneumatic Transfer System and Receipt Facility which reduces considerably operator involvement, provides a safe rapid transport system and minimises any possibility of radioactive contamination. The system can be made fully automatic and ease of maintenance has been ensured by the design.

INTRODUCTION

Reprocessing operations, in common with many more conventional chemical processes, require sampling of the liquor streams at the various stages of the process. These samples may be for process plant control, effluent control, in-line analysis checks, product specification checks, accountancy etc.

In a reprocessing plant irradiated fuel assemblies from reactors are dissolved, the processing of the resultant solution gives rise to varying levels of radioactive solutions and it is therefore necessary to provide the appropriate levels of containment and biological shielding. This imposes certain restraints on the sample taking process, and depending on the elegance of the system employed, a significant time may be taken in delivering a sample for analysis. Overall sample delivery and analysis time may be very important in the case of sentencing, and less important in the case of accountancy. Any reduction in either sample taking time or sample delivery time can be of significant benefit to plant operations.

PRESENT SAMPLING METHODS

The radioactive solutions are contained in tanks in shielded cells and representative stream of the solution is transferred outside the cell to a bulge where a sample is taken from this stream by a hypodermic needle. This operation necessitates a process worker to enter the active area in order to manually take a sample.

The level of activity will determine the sampling method to be used e.g. direct or remote handling. The sample is obtained by placing a pre-evacuated bottle (typically 14-40 ml capacity) over the hypodermic needle.

Prior to actually taking a sample, steps may be taken to ensure that it will be truly representative. This will usually involve either agitation of a tanks contents or continuous circulation of liquor through a sampling loop, or both.

Transport of the samples between the plant and the laboratory is by means of suitably shielded containers.

With the decision to build a new complex at Sellafield to process A.G.R. and Water Reactor Fuels the method of sampling was re-examined and taking account of operational experience at Dounreay on the use of pneumatic transfer of process liquor samples from plant to laboratory and the development of semi-automatic sampling units. A specification for the new system was derived as outlined in the following.

DESIGN CONCEPTS

Design Criteria

1) Ensure radiological protection at all times
2) Conform with applicable safety codes and process regulations
3) Minimise operator involvement
4) Simplify maintenance procedures
5) Reduce overall sampling times
6) Capability for greatly increased sampling demand

Design Principle

In general two liquor supply systems are used, direct needle and Vacuum Operated Slug Lift (VSoL), both systems have proven reliability, but the VSoL system is preferred where accurate accountancy samples are needed. The latest disposable needle tip used in conjunction with a suba seal cap provides a reliable liquor/vacuum containment.

The system would need to be fully automatic, requiring no operator involvement in the active areas.

The manual operations needed to service the system are carried out in non active areas.

The sampling system must provide a maximum throughput for carriers.

Modular construction would minimise the maintenance operations in active areas.

All motors, solenoids and control devices should be positioned outside the containment.

AUTO SAMPLING SYSTEM

Typical Operating Cycle Times (Refer to Fig. 1.)

A typical cycle time for obtaining a sample of active liquor from a sample point 1Km from the analysis laboratory would be approximately 40 minutes.

This figure is based upon cycle times for the automated mechanical handling units, and other known cycle times for such items as the diverters used to set the transport route, and also the actual carrier speed during transportation of 6 metres/sec. The auto sampling system comprises of three major elements

1) Mechanical Handling Units
2) Pneumatic Transfer System
3) Control System

Briefly the auto sampling system is based upon transporting a sample bottle safely and automatically between a series of mechanical handling units via a pneumatic transfer system (refer fig).

The mechanical handling units such as listed below are dedicated to the following tasks.

- Sample Bottle-Carrier Despatch
- Automated Sampling
- Sample Bottle Receipt
- Carrier Monitoring
- Carrier Flasking

The units incorporate the necessary control devices.

The system operates under the direction of a supervisory computer and local controllers, which ensures the itegrity of the system during all operations

MECHANICAL HANDLING UNITS

Standard Items of Equipment

The flexibility of the auto sampling system is largely based on the modular design of the mechanical handling units. Arrangement of the units within a system can provide for a fully automatic or semi-automatic system.

The standard modules are:-

1) Carrier Docking Unit
2) Seal Test Unit
3) Robotic Arm

Carrier Docking Unit

This provides the interface between the pneumatic transfer system and the mechanical handling unit chamber. When a carrier arrives from the transfer pipe it is turned through 90° and secured to the chamber docking port. Carriers are despatched by a reverse procedure.

Seal Test Unit

The function of this unit is to check the condition of the docking port seals at relevant times during an automatic cycle. Provision is made for performing two separate tests. The upper seal check is carried out prior to sending a carrier to the docking unit. This check ensures that the robotic arm is sealing the docking port before the pneumatic transfer exhauster is permitted to evacuate the pipe local to the chamber. The lower seal check is applied to the interspace between the carrier and robotic arm seals

The operation of this unit is fully automated and forms part of the overall autocycle. An integrity check is carried out by pressurising the appropriate interspace. The rate of pressure decay is then monitored. Only when the seals are shown to be effective will the auto cycle proceed.

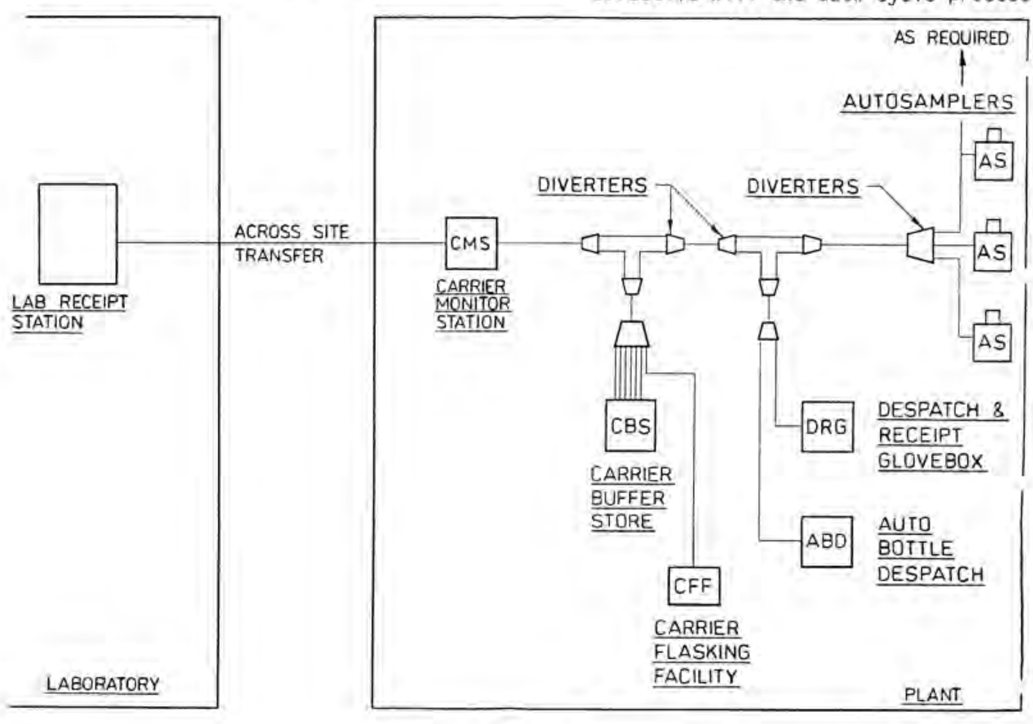

Fig. 1. Typical Autosampling System.

Robotic Arm

The robotic arm performs all the moving functions inside the chamber. The arm movements are pre-programmed for automatic cycles but may be carried out manually, using the facilities provided. During power off condition the robotic arm seals the chamber docking port with a maintained force of approximately 200 lbs.

When a carrier arrives from the pneumatic transfer system, it is automatically clamped and sealed onto the docking port. The robotic arm then rises through a full withdrawal stroke, this movement actuates the arm internal rocker system which releases the lid assembly from the carrier and locks it onto the arm. The arm/carrier lid assembly remains in this condition throughout the automated sequence. The final movement of the sequence replaces the lid in the carrier and locks it into a sealed condition.

Automatic Bottle Dispatch Facility (ABD) (See Fig. 2.)

The purpose of the facility is to automatically despatch empty sample bottles to the various sampling points. This is achieved by loading sample bottles into carriers received from the carrier buffer store and delivering them to the sampling points via the pneumatic transfer system. The sample bottles are individually identified by a bar code label.

Automated sequences performed in the facility are governed by a dedicated control unit, which interfaces with the supervisory controller.

The auto bottle despatch facility is a glovebox with a perspex screen dividing it into two compartments. The screen is for operator safety only and does not provide a seal between the two compartments.

Manual tasks are performed in the right hand compartment which is permanently fitted with gloves. This compartment is referred to as the manual box.

The left hand compartment houses the powered sub-units which operate automatically. Access is via the glove ports provided, but these ports are for maintenance only and are normally blanked off. This compartment is referred to as the auto box.

Empty sampling bottles are posted into the manual box via the special posting facility on the rear wall. Prior to posting in, the bottles are fitted with a suba-seal cap and a unique bar cade label. Using the gloves at the front of the box, the bottles are taken downwards into the storage buckets on the conveyor chain. The conveyor can be manually operated to give access to all empty storage buckets. During this operation an interlock prevents powered operation of the conveyor. Units are provided to prevent wrongly orientated or overlength bottles from entering the loading position. In this event the automatic cycle will not proceed until the fault is corrected.

The auto box houses the powered sub-units which, operating to a programmed sequence, lift bottles from the conveyor and post them into carriers. The basic carrier and bottle manipulation is performed by a standard robotic arm, docking unit and seal test panel combination. The bottle loading unit and conveyor are powered by pneumatic cylinders fitted to the underside of the glovebox. The pneumatic valve panel controlling the cylinders is fitted alongside. The vacuum system comprises of a pump, a pressure switch and a sampling needle inside the box. Worn needles are replaced automatically using the special tools available for autosamplers, only bottles intended for direct needle sampling are pre-evacuated.

The bar code reader is used to scan and identify bottles prior to insertion into a carrier. If a reading cannot be obtained the automatic cycle will stop and a fault situation will be indicated. Carrier speed into and out of the facility is governed by a standard controlled arrival valve. Windows are provided for visual inspection of items inside the auto box.

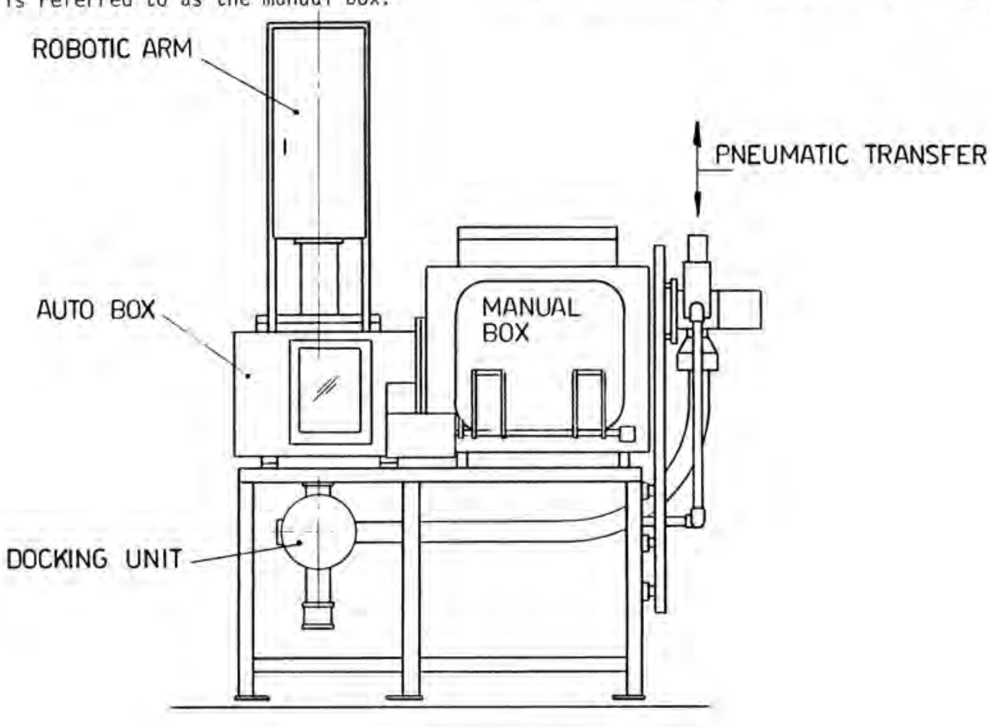

Fig. 2. Auto Bottle Dispatch Facility.

A bottle despatch sequence begins with a sample request at the system supervisory controller. The controller sends a carrier from the carrier buffer store to the ABD facility via the pneumatic transfer system. When the carrier arrives at the ABD docking unit it is detected by the local controls and presented to the docking port. After a seal check has been successfully performed, the robotic arm removes the bottle holder from the carrier and moves it to the bottle loading position. The conveyor moves one pitch to present the next bottle, which is thenloaded into the bottle holder. Bottles requiring pre-evacuation are moved to the vacuum position. They are then positioned above the docking port for identification by the bar code reader. When this has been achieved the robotic arm returns the bottle/bottle holder to the carrier. A seal test is then performed and the carrier moved into the despatch condition to await removal by the pneumatic transfer system. At this stage the ABD local controller informs the supervisor that a carrier is awaiting despatch.

Manual Dispatch and Receipt Facility (D&R) (See Fig. 3)

In small systems with few autosamplers the D & R glove box is used to supply all bottle and needle requirements. In larger systems the D & R glove box is used to supplement the ABD by despatching new needles.

This is a glovebox with two separate sealed compartmentsis used to store carriers, the right hand compartment is used to store new bottles and needles. The bottles are fitted with a suba seal cap and unique bar code label before being posted into the glovebox.

Carrier Buffer Store (See Fig. 4.)

This unit operates in conjunction with the Automatic Bottle Despatch Facility to provide storage for six carriers when not in use.

The unit has an automatic carrier *dispensing* facility comprising of a carrier transfer port, a routing diverter and pneumatic transfer valves. Access is provided to post in new carriers or remove carriers for servicing. Provision is also made for carrier monitoring.

Auto Sampler Unit (See Fig. 5.)

The Auto Sampler Chamber is a containment vessel, with an access port in the base. (Referred to as the docking port). This port is sealed by the robotic arm except when the chamber is in use. A viewing window is provided in the chamber for occasional visual inspection of the internal conditions. A spray wash down facility is fitted into the top of the chamber, for cleansing the interior, if required for maintenance procedures. The active liquor pipes are terminated by nozzles inside the chamber. The nozzles are fitted with renewable hypodermic needle tips which fix and seal by a snap action.

The robotic arm drive is built into the top half of the chamber, it operates to a programmed sequence driven by the stepping motors. The arm movements are monitored by the electrical controls to ensure correct performance. Mechanical safeguards are built into the

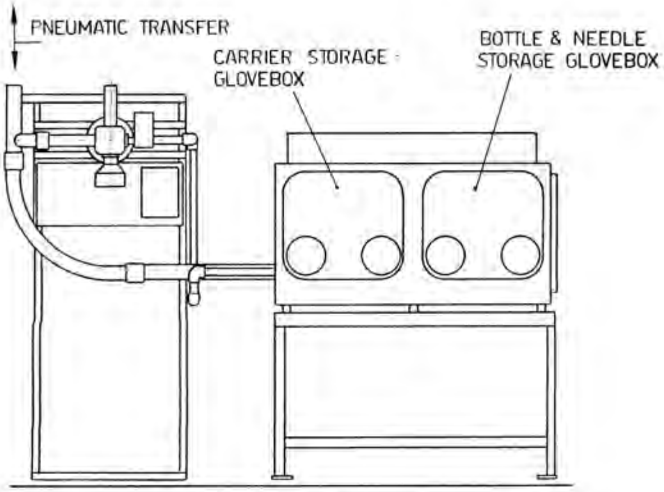

Fig. 3. Manual Dispatch & Receipt Facility.

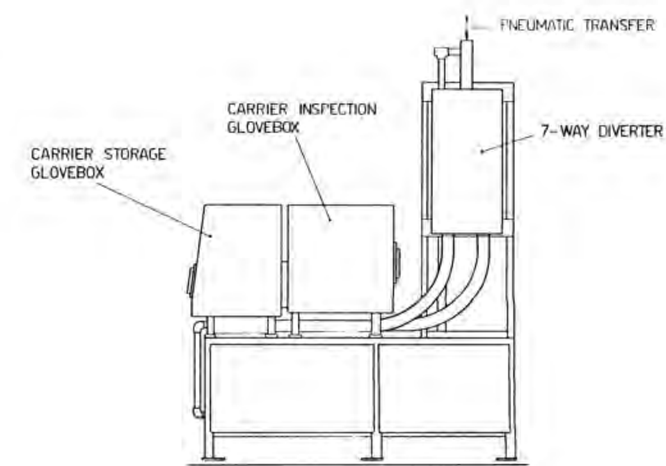

Fig. 4. Carrier Buffer Store.

the drive to prevent damage to the chamber in the event of an interlock fault. The moving parts of the drive are prevented from spreading contamination to the outside of the chamber by a minimum of three separate seals.

When a carrier arrives at the chamber it is automatically docked to the chamber port.

Using linear action only the carrier lid and sample bottle assembly is released from the carrier and locked and sealed to the chamber robotic arm. The same linear action of the robotic arm, releases and draws the sample bottle/carrier lid assembly into the chamber.

The assembly is rotated to the pre-selected sampling position and lowered onto the sample needle. After a sample has been taken, the robotic arm carries out the reverse cycle and replaces the bottle/carrier lid assembly into the docked carrier. The robotic arm seals to the the chamber, andusing the same linear action, the carrier lid is released. The robotic arm simultaneously locks and seals the lid to the carrier maintaining alpha tight seals.

The hypodermic needle tips are renewed by an automated cycle similar to the sampling cycle described above. The service tools that perform the needle renewal operations are carried to the chamber via a standard carrier.

Laboratory Sample Receipt Station (See Fig. 6.)

The function of the station is to receive filled sample bottles or used sampling needles from the plant and post them into the lab. The bottles/needles are delivered to the station inside a transport carrier via the pneumatic transfer system. The station operates in a fully automated manner controlled by a dedicated local controller.

The receipt station is a unit basically similar to a plant autosampler. Sample bottle or needle manipulation inside the station is performed to a programmed sequence by the sub-units.

A sequence begins when the local controls detect a carrier arrival in the docking unit. The carrier is presented to the chamber docking port. After the lower seal check has been successfully performed, the robotic arm removes the bottle or needle from the carrier for delivery into the cell. A sequence finishes when the empty carrier returns to despatch position. The local controller then informs the system supervisor that the carrier is awaiting removal.

A Gamma monitor is fitted inside the station to assess the level of empty carrier activity. This information is used by the supervisory controller to determine the despatch route from the station.

In an emergency situation such as a power failure the station can be manually operated through a full sequence using the special features provided.

Carrier Monitoring Station (See Fig. 7.)

This facility is used to monitor the external activity level of carriers prior to them leaving the process building. Should the permitted level of activity be exceeded, then the supervisory control flags the operator indicating management action is required.

Carrier Flasking Station (See Fig. 8.)

This facility is used for flasking out carriers from the system, if necessary.

It comprises of a shielded carrier receipt unit, a manually operated docking unit and flask housing assembly.

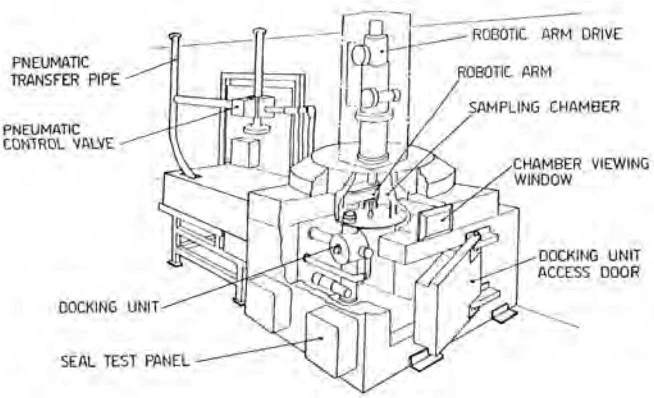

Fig. 5. Autosampler Unit.

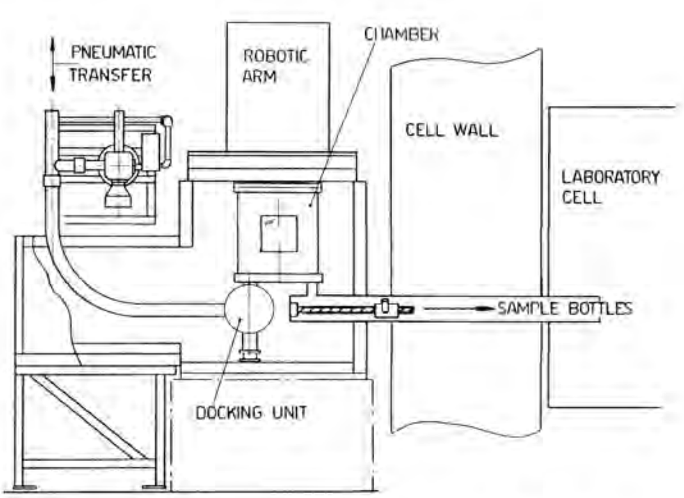

Fig. 6. Laboratory Sample Receipt Station.

Carriers are placed in the flask with the lid intact providing a primary containment, and with the flask top plug locked and sealed in place, a secondary containment is achieved. The flask plug can only be removed by using a special tool held captive in a Flasking Facility, this ensures security during transportation.

PNEUMATIC TRANSFER SYSTEM

The carrier pneumatic transfer system comprises of rigid UPVC tubes with diverters providing junction points. A carrier containing a sample bottle or replacement needle travels through the transfer tubes. Motive air evacuators are positioned at the end of each transfer line, whereby air entering the system is filtered, and exhausted air is returned to the atmosphere via the plant ventilation system.

Tranducers are spaced as required along the transfer tubes, to indicate the carrier position.

An automatically controlled arrival procedure is performed at each mechanical handling unit to reduce the speed of the carrier as it approaches the docking port.

In the event of a power failure, a back up system of compressed air completes transfers already in progress.

Diverter Units

These are used as a multi-junction points in the system and consist of a rotating tube assembly driven by a motorized rack and pinion.

Air Control Valve

This valve controls the air flow in the pneumatic transfer system during carrier delivery or despatch. It ensures that the carrier arrives in the docking unit at a controlled speed thus preventing impact damage. The valve is reset to carrier despatch position during the station automatic cycle period. The movements of the valve are controlled by the pneumatic system controller.

CONTROL SYSTEM

Control Philosophy (See Fig. 9.)

The control of the complete sampling system is based on a distributed architecture utilising programable logic controllers (plc) and computers.

There is an overall system supervisory computer which provides the central operator interface to control and monitor the complete system. This computer is linked to the plant unit controllers which provide dedicated control of a local machine, e.g. an autosampler.

In practice some plant units, e.g. manual gloveboxes, have only very basic control and monitoring requirements that do not warrant a large plc or microcomputer as the local controller.

In these cases pushbuttons, lamps and sensors are hardwired into small programable outstation such as a small plc or multiplexing unit, linked to the supervisory computer.

The supervisory system is responsible for the overall system integrity in terms of the movements and routing of carriers.

Samples are taken on regular scheduled basis to meet process requirements, and are also taken on a one-off basis as required. It is the supervisory computers responsiblity to schedule the regular sample movements and to allocate the requested samples into available time-slots between scheduled movements.

The supervisory system maintains a database of the total systemstatus, which comprises the status of each individual plant device and of the movements and location of each carrier within the system. The method of identification of carriers and samples to the system is via bar codes, unique to each sample. In addition, carriers are color-coded to assist operators in identifying the correct carrier for the requested operation, i.e. sample, needle insertion, needle withdrawal, or maintenance test.

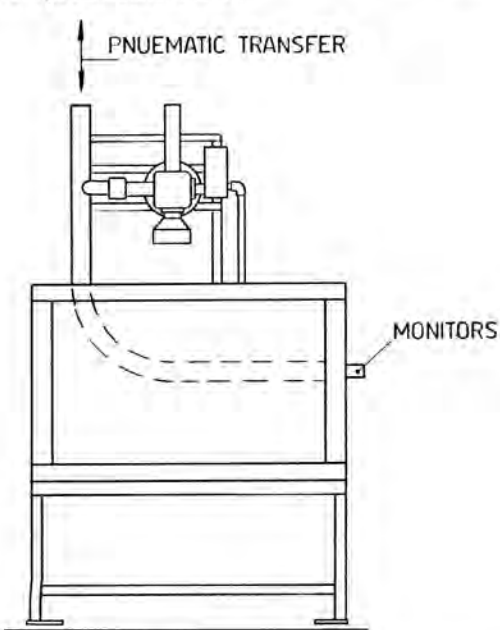

Fig. 7. Carrier Monitoring Station.

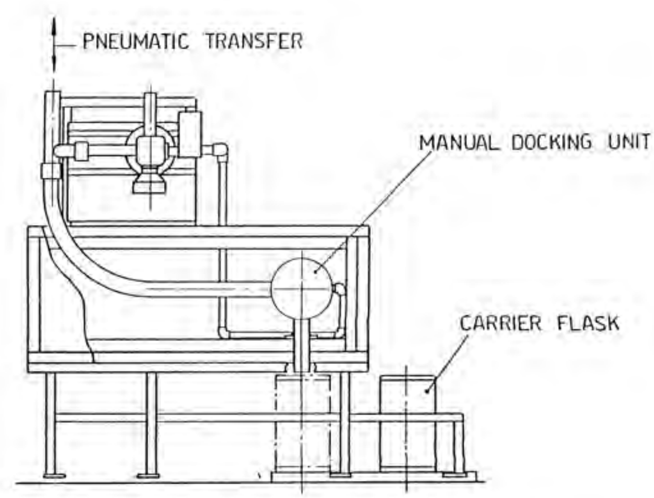

Fig. 8. Carrier Flasking Station.

Local controllers report full status to the supervisor system on fault conditions, position within cycles and usage information.

Before an operation can commence, an availability check is carried out on each device that will participate in the operation. Each device must pass the availability check before a carrier can be sent to the destination. This provides basic assurance that each device is functional and in a valid state to be set up to perform the required operation so that a carrier does not get held up within the system or returned due to an aborted cycle.

Supervisor Computer

This is a minicomputer, typically a DEC pdp11 or VAX, with application software in FORTRAN or Pascal. The system would maintain the database on hard disc or battery backed RAM and if necessary, the disc database could be duplicated (disc shadowing) to provide integrity against disc failure.

The operators interface to the supervisory computer is via a VDU and keyboard, and fault and status messages are logged on a printer.

Autosampler Controller

This is a plc type controller, the three stepping motors for docking, arm lift/lower and arm rotation are controlled by a modular intelligent stepper drives, which have a byte-wide parallel interface to the plc. Motion sensors are provided to give a pulse count verification of the movement of the stepper motors. The required stepper motor movements are stored within the plc, together with status information on seal integrity checks, number of cycles, and the current position and cycle type.

Local Controllers

Dedicated controllers for the lab receipt facility and auto bottle despatch facility are similar to the autosampler controller. This provides commonality of controller types and control equipment. This takes advantage of commonality in the mechanical design of the facility itself.

Manual Facility Control Interface

The operator interfaces for the control of manually operated facilities are via pushbutton panels with lamp indicators. In addition, a mimic of the facility may be provided. A single line 40 character alphanumeric LED display is provided to permit prompts, instructions and warning messages to be displayed to assist the operator. These displays may be driven directly from the supervisory computer, via serial lines or from intelligent outstations.

Supervisory to Local Controller Interface

The linking of the supervisory system to local controllers is via an Ethernet multi-drop network, which is an industry standard.

Fault Reporting

In the event of a fault being detected during a plant cycle, the operation of the sequence is halted, and a status message is sent to the supervisory computer, which logs the fault and alerts an alarm in the main control room. After rectification of the fault a message is transmitted to the outstation (password protected) to either continue the cycle or abort the cycle depending on the nature of the fault and its recoverability.

Maintenance Operations

Local controllers also have a maintenance mode that permits step by step operation of the plant via a hand held terminal connected locally to the controller. Software checks allows only permitted movements to be made, so as to safeguard the system.

This is selected via the supervisory computer so that it knows the type of operation being performed on the outstation.

TYPICAL OPERATING SEQUENCE

At the start of a sampling or needle change operation, the supervisory computer checks the availability of the selected autosampling unit and the sample bottle

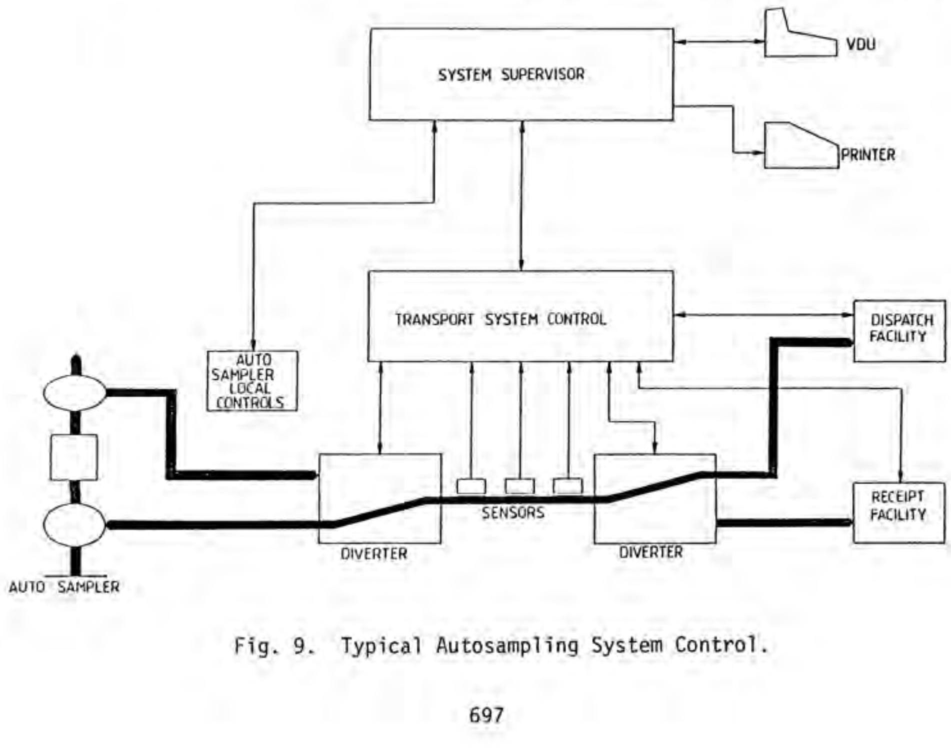

Fig. 9. Typical Autosampling System Control.

receipt facilities. When the checks are satisfactory, the supervisory computer requests a seal integrity test at the auto sampling unit and if positive, instructs the pneumatic carrier transfer system controller to set the route.

The system is programmed to operate in the set sequence. A sample bottle is installed into a bottle carrier and the carrier is positioned in the despatch part of the sample bottle despatch facility.

The carrier pneumatic transfer system is initiated and the carrier is transported to the selected auto sampling unit where it is automatically docked and secured to the port base of the sampling chamber. The seal on the carrier now matches an external seal to the port. The carrier lid and sample bottle assembly are locked and sealed to the chamber robotic arm before being released from the carrier.

The robotic arm has a synchronous latch/delatch mechanism and withdraws the sample bottle/carrier lid assembly into the chamber.

The carrier remains secured to the base of the sample chamber forming a gas tight seal. The robotic arm then rotates towards the pre-selected sample needle and lowers the sample bottle onto the needle which pierces the self-sealing bottle cap. After a sample has been taken, the robotic arm returns the sample bottle/carrier lid assembly into the docked carrier.

This action locks and seals the sample bottle/ carrier lid assembly into the carrier and simultaneously seals the port at the base of the sampling chamber. The carrier is then released and transferred pneumatically to the sample bottle receipt facility at the analytical area.

Interlocks and seal checks ensure that integrity of the containment during transfer operations.

The cycle for renewing the sample needles is similar to the sampling cycle.

FUTURE APPLICATIONS

The Auto-Sampler systems which have just been described, have been developed over the past 5 years, and are now being implemented into new plants at Sellafield.

Four samplers and associated suits are presently being installed in the new Vitrification Plant at Sellafield, and installation of the cross-site transfer lines will commence in 1987.

A large system comprising of more than forty samplers and supporting equipment is to be installed in the THORP plant.

Design studies are in hand for a scheme to back-fit six samplers and supporting equipment into building B205, the present centre of reprocessing operators at Sellafield.

The system is applicable to any industry where it is necessary to sample toxic materials.

It is also suitable for use in the pharmaceutical industry where it is necessary to maintain sterile conditions.