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Summary

The vacuum equipment of the magnetic spectrograph Little John is described. The system is characterized by the following special features:

* The sliding exit flange of the target chamber can be moved to the desired angle of observation without affecting the high vacuum.

* The pressure maintained is less by a factor of ten than the pressure in the incoming beam tubing.

* The vacuum system is divided into several separate pumping sections.

* Ground loops are strictly avoided.

* All actual states of relevance are fed back to the control panels.

* The vacuum installation is protected by hardware interlocking systems as well as by a real time program written in FORTRAN in cooperation with CAMAC interfacing.

DAS VAKUUMSYSTEM DES KARLSRUHER MAGNETSPEKTROGRAPHEN "LITTLE JOHN"

Zusammenfassung

Die Vakuumanlage des Magnetspektrographen Little John wird beschrieben. Spezielle Charakteristika der Anlage sind folgende:

* Der Austrittsflansch der Targetkammer ist unter Vakuum verstellbar.

* Der Druck im Spektrographen ist um den Faktor 10 kleiner als der Druck im Strahleintrittsrohr.

* Das Gesamtsystem ist in mehrere Pumpsektionen unterteilt.

* Erdschleifen sind strikt vermieden.

* Alle relevanten Istzustände werden zurückgemeldet.

* Die Anlage ist durch Hardware-Verriegelungen und durch ein Echtzeit-Überwachungsprogramm geschützt, das in FORTRAN geschrieben ist und CAMAC als Schnittstelle benutzt.

Contents

1. Introduction

The Karlsruhe Magnetic Spectrograph "Little John" /1/ measures the momenta of light charged particles from nuclear reactions induced by various ion beams provided by the Karlsruhe Isochronous Cyclotron. The focal distance of this spectrograph can be varied so that the momentum resolution can be chosen in way appropiate for the experiment. The spectrograph can be rotated round the target position from - 3 degrees to + 70 degrees or from + 17 degrees to + 90 degrees without breaking the vacuum.

This report presents specific informations about the concepts /2/, the layout, the computer control and some important details of the vacuum system of the spectrograph. It is intended to facilitate a reasonable handling of the vacuum system and its components.

2. Installation

2.1 Layout

The vacuum system of the Magnetic Spectrograph is schematically shown in Fig. 1.

From the very beginning, only two high-vacuum pumps have been provided, one beneath the target chamber and the other downstream near the sextupole, at the detector arm. Correspondingly, the system was divided into two main sections by a valve near the sliding exit flange of the target chamber. This concept allows to flood and evacuate the two main sections separately and thus facilitates access to the experimental setup or to the focal plane detector without breaking the vacuum in the other main section. Another valve located near the entrance flange of the target chamber was provided in order to separate the spectrograph vacuum system the experimenter is responsible for which from the beam guiding system controlled by the cyclotron operating staff.

In the meantime, some extensions of the original concept have been discussed and implemented:

* Two additional flanges are provided for high-vacuum pumps, one between the quadrupole duplet and the dipole magnet where free space happened to be available, the other immediately in front of the focal plane detector where an excessive degasing rate caused by the organic window foil was observed /3/.

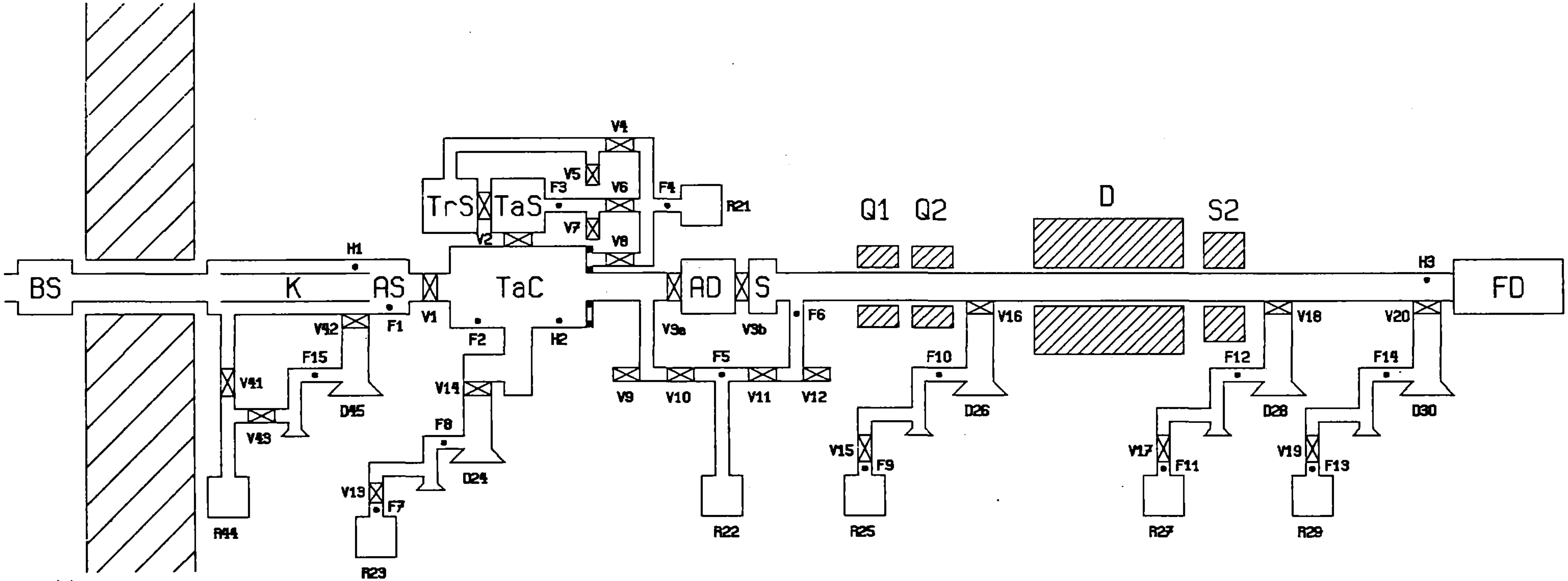

Fig. 1: Layout of the Vacuum System

V: valve
R: rotary pump
D: diffusion pump
F: fine vacuum gauge
H: high vacuun gauge

BS: beam stopper
K: kryotrap
AS: active slit system
TaC: target chamber
TaS: target sluice

TrS: transport sluice
AD: acceptance detector
S: passive slit system
FD: focal detector

* A further main section, the "cryotrap", has been introduced at the entrance of the target chamber. This section is supplied from a high-capacity high-vacuum pump as well as from a cryosurface cooled down to the temperature of liquid nitrogen in order to achieve a pressure ratio of more than ten between the pressure in the beam entrance tube (some 10^{-5} mbar) and the pressure required in the spectrograph itself (better than 10^{-6} mbar). Since the cryotrap was previously considered to be a part of the common beam tubing and not of the magnetic spectrograph it has its own control panel.

  The cryotrap section comprises also a crossed slit system the edges of which are made of scintillating material ("active slits").

* Between the target chamber and the quadrupole duplet a passive crossed-slit system, which is part of the spectrograph chamber section, and an acceptance detector have been introduced. The housing of this detector which is provided with very thin window foils is separated from the target chamber by the upstream valve V3a and from the spectrograph chamber by the downstream valve V3b. When the acceptance detector is removed - this may be necessary if the material inserted by the acceptance detector unduly affects the particle spectra to be observed - both V3a and V3b can be switched simultaneously by the push-button labeled "V3" on the control panel Ü3 / Ü5 (see chapter 3.1), provided that the pressure differences across V3a and V3b do not exceed some ten mbars. However, when the acceptance detector is in place, this possibility of control will be locked by a key switch on the acceptance detector control board, and valves V3a and V3b can be opened individually.

There are four main vacuum sections as shown in Fig. 1:

Separating Valve	Main Vacuum Section	Volume of the Section
Beam entrance valve		
	Cryotrap	25 litres approx.
V1 (50 mm diam.)		
	Target chamber	30 " "
V3a (50 mm diam.)		
	Acceptance detector	5 " "
V3b (80 mm diam.)		
	Spectrograph chamber	55 - 170 " "

with the appendent subsections like diffusion pumps and target sluice.

Altogether, the vacuum system consists of

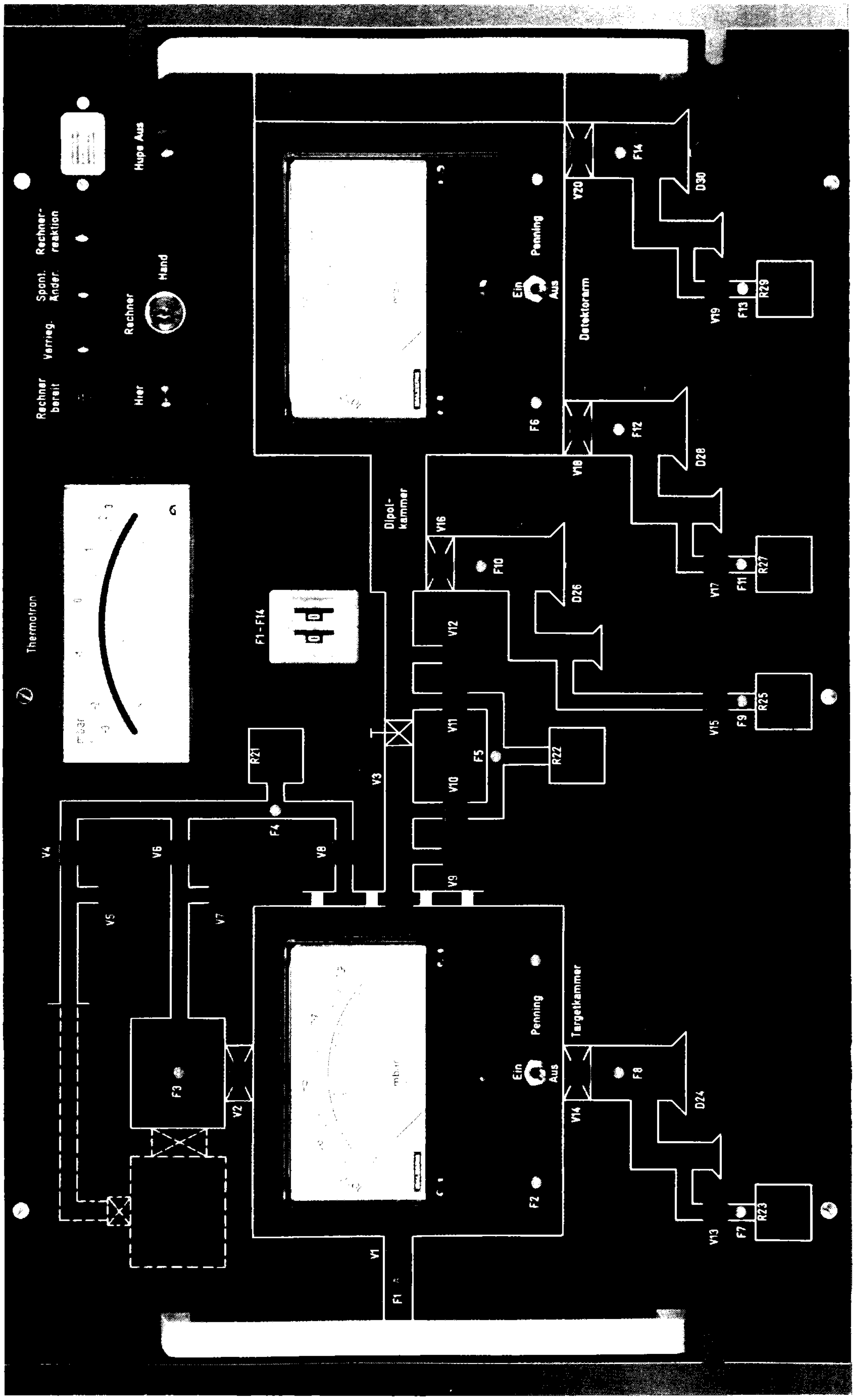

Fig. 2: One of the Control Panels of the Vacuum System

8 rotary pumps: R21, R25, R27, R29 of 1.5 m^3/h each,
R44, R23 of 4 m^3/h each,
R22 of 12 m^3/h,
"Minni"-pump;
5*2 = 10 diffusion pumps:
D45 and D24 of 700 + 180 litres/s each,
D26 and D28 of 280 + 40 " " ,
D30 of 135 + 40 " ;
24 valves;
15 fine-vacuum gauges;
3 high-vacuum gauges.

Each main diffusion pump is backed up by a smaller prepump in order to reduce effectively backstreaming of oil vapor from the rotary pumps. The backing up pumps R21, R25, R27, and R29 are dimensioned so as to comply with the very small gas rates in normal, leak-free operation. The bigger rotary pump R22 evacuates either the target chamber or the spectrograph chamber down to its ultimate pressure within a few minutes. R21 has three functions: either to maintain a low pressure between the double seal of the sliding tape of the target chamber, or to evacuate the target sluice, e.g. after replacement of the target holder, or to evacuate the target transport sluice planned to handle oxygen-sensitive targets in future.

2.2 Design Concepts

The high demands on final pressure and on freedom from oil contamination justified a fairly expensive concept with the following features:

a) The main diffusion pumps are backed up by smaller diffusion pumps in a tandem constellation in order to avoid oil vapor backstreaming from the rotary pumps into the vacuum vessels.

b) The sliding seal of the target chamber is doubled with the space between the two seals evacuated.

c) In most cases modern seals with external supporting ring, e.g. Edwards Co-Seals, are used. This technique avoids the enclosure of small gas volumes which can otherwise escape only through the very tight slits between the flange surface and the centering ring of conventional seals.

d) All aggregates (pumpes, valves) are controlled from a common control panel outside the experimental hall (Fig. 2), about 25 m away from the spectrograph facility; for convenience, a second control panel has been provided near the spectrograph itself.

e) The actual state of all aggregates (on/off, open/closed) are indicated simultaneously on both control panels by (yellow) LEDs.
Note: The on/off state of the diffusion pump heaters and of the rotary pump motors is monitored by relays sensitive to electrical current; the tacho-generator signals delivered by modern rotary pumps are not used in this installation.

f) The fine-vacuum pressure levels (above/below the preset thresholds, nominally 0.1 mbar) are measured in each section and in each subsection (Fig. 1) and are indicated simultaneously by (red/green) LEDs; the analog pressure values can be read, one at a time, by a switchable analog meter (10^{-3} to 10^{3} mbar range).

Actually, the fine-vacuum gauges which measure the pressure inside the diffusion pumps are not mounted near the intake flange as it could appear from the function schemes on the Ü3 / Ü5 panels (Fig. 2) but at the outlet flange of the main diffusion pumps, i.e. at the intake flange of the smaller backing up diffusion pumps.

Moreover, the high-vacuum pressure levels and analog values in the three main sections (cryotrap, target chamber, and spectrograph chamber) are shown simultaneously by additional red/green LEDs and analog meters (10^{-7} to 10^{-3} mbar range).

In addition, an acoustic signal indicates if the high-vacuum pressure in the cryotrap and/or in in the detector arm fails to be lower than the preset thresholds, nominally 10^{-6} mbar.

g) Interlocking relays protect the system against the most important technical failures and operational faults like

destruction by mechanical collision, e.g. between V2 and the target rod, or excessive force, e.g. by too high a pressure difference across big valves;
burning of the oil in the diffusion pumps as a result of air leaks or spontaneous air intake, or insufficient cooling;
loss of cooling water in case of tube rupture;
contamination of the vacuum chambers by volatile impurities coming from the entrance tube;
radioactivation of the beam entrance valve in its closed state by the primary beam.

h) Besides manual operation mode, the control commands as well as the aggregate and the pressure states can be surveyed by a computer program in order to prevent unallowed actions and conditions. With the only exceptions of a cold starting procedure and of a shutdown procedure, no automatic sequence of actions will be performed by the computer in order to save the desired flexibility of operation.

On the other hand, the desired pressure of better than 10^{-6} mbar can be obtained with the standard vacuum techniques, e.g.

Rack # 8

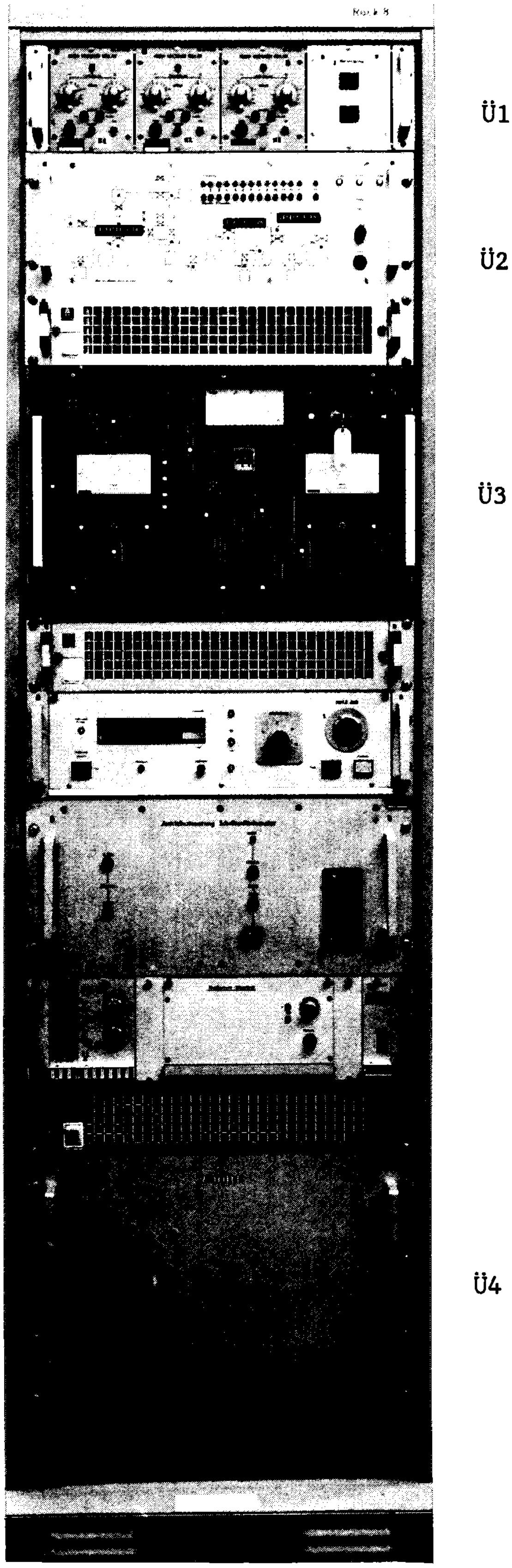

Fig. 3: The Control Rack for the Vacuum System in the Experimental Hall

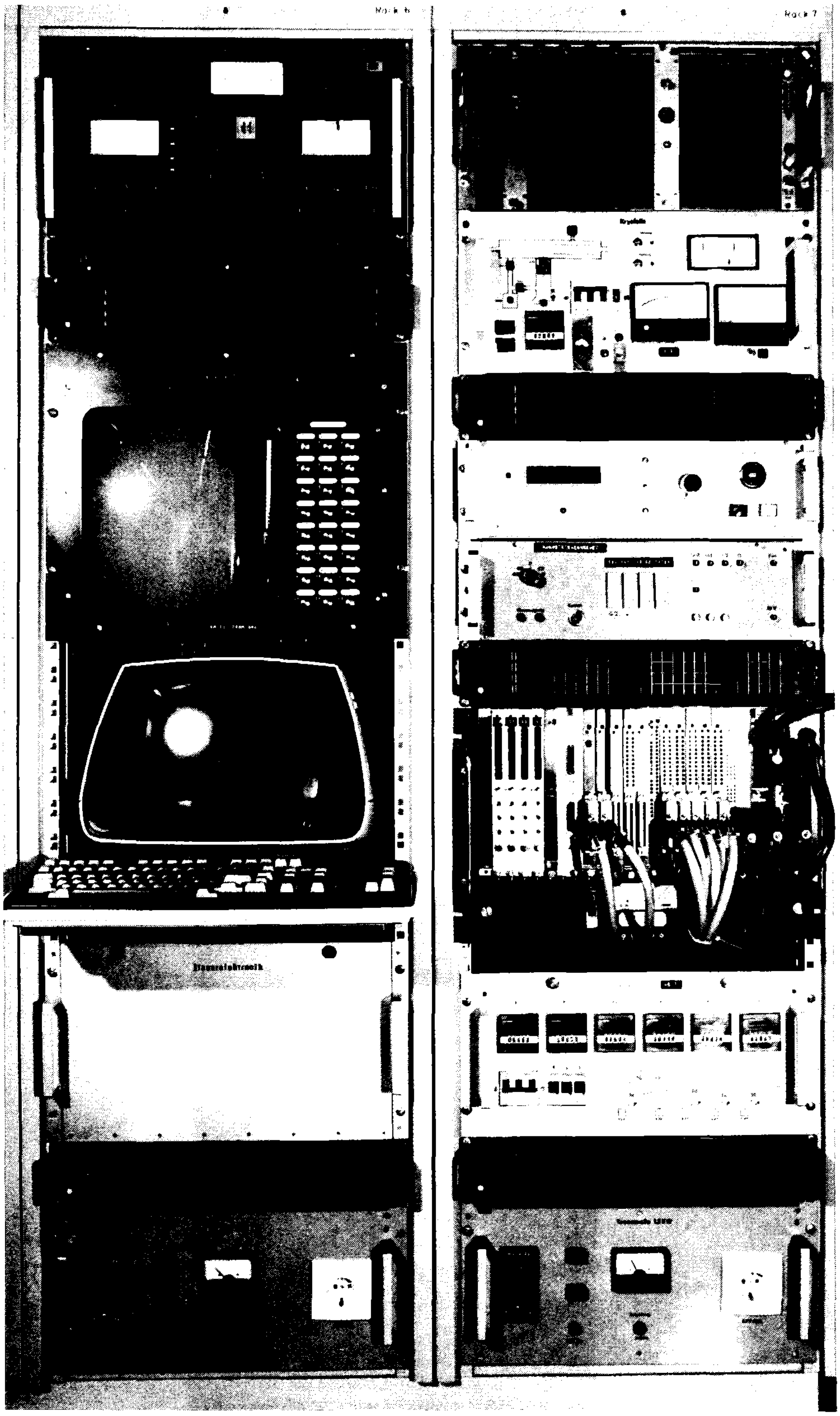

Fig. 4: The Control Racks for the Vacuum System in the Measuring Area

* Viton seals, either completely dry or slightly wetted with silicon grease,

* water-cooled baffles,

* aluminium valves,

* stainless steel chamber surfaces,

* rotating or even sliding O-ring seals or Simmer rings (for valves, slits, target rod, rotatable detector mounting, etc.).

3. Control Hardware

3.1 Configuration

The control hardware is distributed among several crates, some of them installed in rack # 8 in the experimental hall (Fig. 3), others in racks # 6 and # 7 outside the experimental hall in the measuring area (Fig. 4):

Ü1 (in rack # 8) contains 4 modules: The three high-vacuum monitors H1 to H3 mentioned above, and a self-locking power relay delivering the power for high-voltage supply to detectors possibly operated inside the target chamber; the power will be shut off by a pressure rise either above the H2-threshold (target chamber) or above the H3-threshold (spectrograph chamber).

Ü2 (in rack # 8) contains 14 fine-vacuum monitors F1 to F14; the locations of the related gauges are shown in Fig. 1.

Ü3 (in rack # 8) constitutes one of the two control panels. Arranged in a grooved situation scheme, it contains the command push-buttons each with an integrated LED indicating the actual state of the corresponding aggregate. In addition, Ü3 contains (on the right hand side of each diffusion pump symbol) a ready-for-operation LED, furthermore the binary pressure level indicators F1 to F14, H2 and H3, a Thermovac meter switchable to the gauges F1 to F14, and two Penning meters belonging to the gauges H2 and H3.

Ü4 (in rack # 8) serves as a distributor, especially to separate the power lines from the signal lines of the valve connecting cables. Moreover, Ü4 contains some interlocking relays, see 3.2.

Ü5 (in rack # 6) constitutes the other control panel. Ü5 is identical to and interchangable with Ü3. Only one of them can be active at a time, that means sensitive to push-button commands.

Ü6 (in rack # 6) contains the control electronics. From the point of view of electronics both response signals and commands are realized by switching electrical contacts. The status signals, some of them coming directly from the aggregates via Ü4, others from the power monitors (for rotary pump motors and diffusion pump heaters) installed in Ü7, are looped through Ü3 and Ü5 (where they drive the LEDs) to Ü6, where the contact chatter is eliminated electronically. Then, they are transmitted to the CAMAC input modules (see below). The command signals the contact chatter of which is eliminated already in Ü3 and Ü5 are transmitted to Ü6. Here, a multiplexer decides which of the two control boards Ü3 / Ü5 should be sensitive, thus allowing either the commands from Ü3 or the commands from Ü5 to trigger a toggle flipflop. In case of manual control, the output levels of the command flipflops directly engage the power relays in Ü7, see below.

The output levels of the command flipflops are directed to the CAMAC change-of-state input modules and, in case of surveillance by computer, they are read by the computer. The computer either engages the power relays in Ü7, provided the command is recognized as acceptable, or resets the command flipflop in Ü6 to the previous state, thereby canceling the unacceptable command.

Morover, Ü6 contains some auxiliary circuits, for example to clear all command flipflops after switching on the power, or to drive (manually resettable) red blinking LEDs one of them indicating the rejection of any unallowed command, and the other any reaction of the computer itself in order to respond to a dangerous change of state.

Ü7 in rack # 7 houses the power relays for the various aggregates. These relays are opto-coupled, spark-free switching thyristor relays. For the diffusion pump heaters and for the rotary pump AC-motors, current sensitive relays with one single threshold, and for the three-phase motor of R22, a power sensitive relay with a lower and an upper threshold are provided to monitor the on/off state. Moreover, Ü7 contains six counters which totalize the working times of the rotary pumps R21, R22, R23, R25, R27, R29. Arranged in a simplified function scheme, red LEDs flash when the cooling water flow for any of the diffusion pumps D24, D26, D28, D30 falls short of the related rotameter threshold.

Ü8 in rack # 7 serves to operate the cryotrap. It contains a separate control board for the aggregates V41, V42, V43, R44, and D45 together with the corresponding electronic circuits and thyristor relays. The pressure level and the analog value at the outlet flange of D45 are permanently shown. The same holds for the high-vacuum level and pressure, H1, inside the cryotrap itself. By contrast, the fine-vacuum pressure inside the cryotrap, F1, is shown on both control panels Ü3 and Ü5. Finally, Ü8 allows to cool or heat the copper cryotube (60 mm in diameter and 320 mm in length). The temperature is controlled by a front panel meter the lower and the upper contacts of which can be set at any value between - 150 °C and + 100 °C.

The connectors on the rear side of the crates and the connecting cables are labeled as "m.n", where "m" means the crate number (1 - 8) and "n" is a one-digit or two-digit consecutive number.

In order to guarantee a sufficient operating reliability, the following hardware precautions have been provided:

* All optical indicators are long-lived LEDs so that the probability of mistakes originating from dead indicators is strongly reduced.

* In order to avoid undesirable ground loops, racks # 6, # 7, and # 8 are powered by means of special transformers which separate from each other the protecting earth lines of the main supply and of the system. The bodies of the vacuum gauges are electrically insulated from the spectrograph body and the reference potentials ("electronic ground", "GND", "0 V") of the DC-supplies of the various crates, although interconnected, are insulated with respect to the chassis. The target chamber the potential of which is floating may serve as an electrical shield for built-in detectors or current probes if connected with the electronic ground.

Detailed descriptions of crates Ü1 - Ü8 may be found in references /4/.

3.2 Interlocking Systems

Some interlocking relays protect the vacuum system in case of malfunction of aggregates or in case of vacuum leaks or serious mistakes in operation. These precautions will work regardless of whether the control program is executing or not. The hardware interlocks provided are:

* The heaters of the diffusion pumps become or remain switched off if the cooling water monitors fail to respond or if the safety thermoswitch attached to the cooling coils is open.

  We have to note that the locally fixed diffusion pumps D45 and D24 on the one hand and the diffusion pumps D26, D28, and D30 moving with the spectrograph support on the other hand have separate cooling water systems; if one of the cooling water monitors of a given system fails to be closed, all diffusion pumps of the same group are affected.

* The power supply for a detector operated inside the target chamber becomes or remains switched off if H2 or H3 rises above the respective preset threshold.

* V1 becomes or remains closed if H1 rises above the preset threshold.

* The beam stopper placed in the beam entrance tube becomes or remains inserted if V1 is closed.

* V2 remains open when the target rod is inserted into the target chamber, and the target rod can not be moved down if V2 is not completely opened.

* V3a and V3b will remain closed if they are locked by a key switch on the control panel for the acceptance detector which is thereby protected from pressure changes in the adjacent vacuum sections.

* For each main vacuum section, the valves V1, V2, V3a, V3b which separate the main vacuum sections from each other and the valves V42, V14, V16, V18, V20 above the diffusion pumps become or remain closed if the fine-vacuum pressure inside this section rises above the preset theshold.

* The Edwards flap valves and the VAT sliding valves should remain closed if the absolute value of the pressure difference across the closed valve exceeds a given small value (tentatively 30 mbars, really 60 mbars). Since no differential pressure monitor with a sensitivity of the order of 30 mbars, independent of the direction of the pressure difference and independent of the pressure level between 0 mbar and 1000 mbars, was commercially available, a prototype was designed and tested.

4. Computer Control

4.1 Philosophy

The function of the computer control program /5/ is primarily

* to check the entirety of the states of the vacuum system at the instant the program takes over the responsibility (this is the case either when the key switch on the active control panel is in the computer mode ("RECHNER") position and the program has just been loaded, or when the program was already loaded and the key switch is turned from the "HAND" to "RECHNER" position);

* to check each switching command given during computer mode operation by pressing a push-button on the active control panel;

* to check each change of state of the vacuum aggregates and the vacuum meters if the change is a consequence of a manual command or if it is possibly a spontaneous, dangerous event.

Therefore, the main intention is to ensure the reliability of operation of the vacuum system by detecting unallowed states or actions which may occur (and part of them occurred in fact) in manual operation, e.g.

* opening of the backing up valve before the rotary pump is put into operation;

* opening of the backing up valve while the flooding valve is still open;

* continuation of fine-vacuum pumping when the ultimate pressure is already reached;

* continuation of heating the diffusion pumps when the pressure at the inlet or at the outlet is higher than permitted;

* opening the valve above a diffusion pump before the diffusion pump is ready for operation;

* pumping simultaneously by rotary and diffusion pumps;

* shutting off the rotary pump before the diffusion pump is cooled down.

Economic considerations, e.g. saving electrical power by switching off rotary pumps not actually in use, are playing a minor role.

Because the enormous number (> 10^{15}) of possible combinations of states (36 aggregates plus 15 vacuum gauges, each with at least two possible states: on/off; open/closed; good/bad) not every possible combination is logically checked for acceptability. Instead, a minor number of doubtless allowed combinations is defined whereas all others are declared as forbidden. The allowed combinations of states cover the following four normal modes of operation

shutoff (leak testing),
flooding,
fine-vacuum pumping,
high-vacuum pumping,

for all sections / subsections of the vacuum system and their combinations.

In general, only the primary conditions, e.g. "rotary pump on?", are tested by the program and not the logical consequences arising from these primary conditions, e.g. "fine-vacuum pressure above the rotary pump good?" Tests of consecutive states are performed only if necessary, e.g. for deciding wether a diffusion pump is allowed to be switched on.

The reactions of the program depends on whether it checks a state or a command. In case of an unacceptable initial state, no special correction is attempted, but the whole vacuum system is put into a safe, predefined standard condition, regardless whether a locally confined correction might be sufficient. By this means, the operator is hardly punished in the possible case of maloperation preceding the computer mode operation.

The same global reaction of the program occurs if during computer mode operation a spontaneous, dangerous change of state is encountered by the programm. (Note that fine-vacuum pressure above the preset threshold cause closure of the separating valves of the affected section by hardware interlocking). The discrimination between expected or harmless changes of state, on the one hand, and dangerous, unexpected changes of state, on the other hand, is based on the following definitions:

* All changes of state "high vacuum good" and "high vacuum bad" are listed only, without causing any other reaction.

* All changes of state going in the direction "open", "on", "ready for operation", and "fine vacuum good" are treated as harmless events.

* The changes of state in the direction "fine vacuum bad' are treated as follows:

Pressure rise	is judged as harmless if after a delay of 5 min
F1 >	either V41 is closed or F1 <
F2 >	either V10 is closed or F2 <
F3 >	(always)
F4 >	either R21 is off or F4 <
F5 >	either R22 is off or F5 <
F6 >	either V11 is closed or F6 <
F7 >	either R23 is off or F7 <
F8 >	either V13 is closed or F8 <
F9 >	either R25 is off or F9 <
F10 >	either V15 is closed or F10 <
F11 >	either R27 is off or F11 <
F12 >	either V17 is closed or F12 <
F13 >	either R29 is off or F13 <
F14 >	either V19 is closed or F14 <
F15 >	either V42 is closed or F15 <

A temporary slight pressure rise in a rotary or diffusion pump subsection may occur if e.g. oil in the diffusion pump degases during the warming up period, or if the valve on top of a diffusion pump is opened while not allowing the vessel to degas properly. In principle, the amount and/or the tendency of pressure excursion would provide a better criterion of severity but this information is not available to this system. So, the computer decision has to be based on the time criterion.

* All changes of state which occur within a delay of one second after the corresponding command are judged as being caused by this command.

* All other changes of state will initiate the safety shutdown procedure, see 4.2.

Note that the vacuum system is surveilled exclusively by interrupt control; no cyclic reading of states is provided.

In case that during computer mode operation a push-button command is given which would result in an unallowed operational state the program ignores the command and resets the related command flipflop (see 3.1) to the previous state. Moreover, any consecutive push-button command, may it be acceptable or not, is ignored by the program until the operator has acknowledged the red blinking LED labeled "VERRIEGELT". In this way, the operator is strictly reminded of his attempt to perform a forbidden action.

Besides the preventive functions of computer control there are three other objects, namely:

* to list each action and each change of state in connection with the vacuum system in order to inform the next operating shift in rather long experiments and to allow an analysis of the history at some later date in case of an accident;

* to warn the operator by an acoustic signal if the ultimate aim, namely high-vacuum pressures H2 (target chamber) and H3 (spectrograph chamber) below the preset thesholds, is not attained;

* to perform an automatic cold starting procedure of the vacuum system at the beginning as well as an automatic shutoff procedure at the end of an experimental time in order to support the shift personnel.

4.2 Implementation

At the early stages program development was supported by a purpose-built prototype of the control hardware /7/ the function of which was limited to one pumping section of the real spectrograph.

It was decided to write the vacuum control program in FORTRAN considering that at a later stage not only other control duties, e.g. control of magnet currents, stepping motors etc., but also the complete job of on-line data elaboration should be incorporated in the same program system. (Meanwhile, on-line data evaluation and presentation has been delegated to a LSI 11 computer.) The Data General FORTRAN IV is well suited for applications like the control of technical processes because it incorporates the following features:

* The built-in system routines for bit manipulation allow to store and test 16 commands or states in one single two byte word.

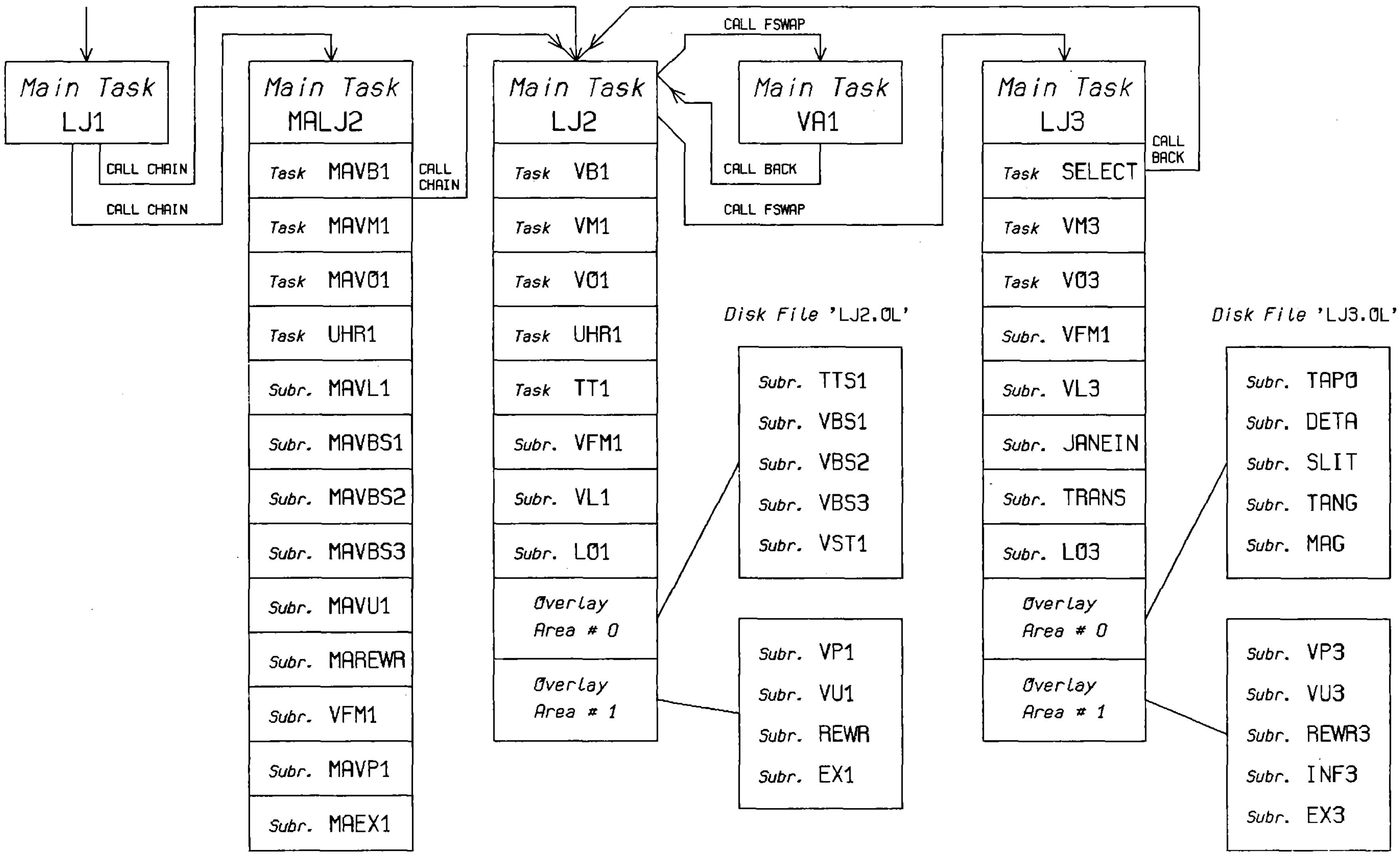

Fig. 5: Structure of the Control Program System for the Vacuum System

* The multitasking feature allows, contrary to calling a subroutine the start of which is predefined by the source program, the asynchroneous start of a task which may e.g. serve a spontaneous demand.

* The abilities of "chaining", "swapping", and overlay structuring allow to segment a voluminous program into smaller units which are loaded from disk on demand; although the program region of the NOVA 2 main memory includes only 36 k bytes, an extensive program system can be run on this small computer.

* Finally, a complete set of assembler-written FORTRAN subroutines has been available to handle keyboard and CAMAC interrupts and to perform CAMAC "single actions" /8/.

In a specific sense, the vacuum control program has the feature of true real-time programs. In this respect, however, two questions are to be answered quantitatively:

a) What delay is allowed within which the program should react to a random demand (interrupt, CAMAC-LAM)?

b) What are the smallest time difference and the maximum number of nested demands to be expected?

The problem a) has been solved by defining decreasing priorities for the various service tasks in the following order:

service task for change-of-state interrupts,
task executing the safety shutoff procedure,
service task for push-button command interrupts,
service task for teletype interrupts,
service task for the one minute CAMAC-clock interrupts.

Moreover, the first two tasks mentioned above are resident in the main memory, that means, they are available immediately, whereas the not time-critical service tasks for manual interrupts call disk-resident overlay subroutines.

The problem b) is commonly solved by the well-known stack technique which buffers those interrupt demands which arrive before the last one has been processed completely. However, this technique is not applied in the present program version. As a consequence, it may happen that some nested interrupts get lost and that the states of the command flipflops fail to correspond to the actual states of the aggregates or vacuum gauges. To overcome this seldom situation, a teletype command, VUPD, is provided which updates the command flipflops, see below.

As shown in Fig. 5, the program system consists of five main tasks. Among these, you will find LJ1 which initializes and stores on disk some global parameters (some of them describing the periphery to be controlled, others beeing parameters for interprogram communication), and VA1 which performs the initial checkup of all aggregates of the vacuum system. Both are single-task programs, whereas MALJ2, LJ2, and LJ3 recognize interrupt demands and start the appropiate service tasks as described before.

The multitask programs MALJ2 and LJ2 can be chained from LJ1 either directly or successively. MALJ1 performs an automatic starting procedure of the vacuum system. LJ2 accepts manual as well as device interrupts. Each push-button command and each change of state is protocoled in a short form on the terminal screen (in rolling mode) and, optionally, on the printer. Moreover LJ2 allows four teletype commands, which have to be typed in after releasing an ESC-interrupt:

VSTA (lists the states of all aggregates and gauges of the vacuum system on the terminal screen and/or on the printer),
VUPD (updates the command flipflops),
VOFF (initiates the shutdown procedure),
EXIT (terminates the program).

In the multitasking programm LJ3 /6/ the control of seven stepping motors (four acceptance slits, target position, target angle, detector angle) and of the exciting currents of the four spectrograph magnets (Q2, Q1, D, S2) is incorporated. While the surveillance of the vacuum system is still operative both vacuum control panels Ü3 and Ü5 (see chapter 3.1) 3.1) are inactive. LJ3 can be accessed only from LJ2 via swapping which can be effectuated by pressing the TAB key. The user is guided by menues.

4.3 Operation

Independent of whether the manual or the computer mode of operation of the vacuum system is preferred, one has to actuate the aggregates in the appropriate sequence by push-button commands allowing, perhaps, an appropriate delay. Only during execution of the cold starting and the shutdown procedures the commands are given by the computer. In the computer mode of operation, the operator is relieved from his responsability by the program. Therefore, it is advisable to take advantage of this offer.

Reference /9/ describes how to load and to run the progam in detail. In any case, the user must observe the following general rules:

* The success of each command can (and should) be verified by looking at the LEDs and the vacuum meters on the control panels and, possibly, at the protocol output delivered by the program.

* With the only exception of backing up of heated diffusion pumps, fine-vacuum pumping of the various spectrograph sections should be finished as soon as the ultimate pressure is reached in order to avoid reflow of oilvapor. Allow degasing for a while and repeat fine-vacuum pumping for a few minutes!

* Unused rotary pumps should be switched off.

* Before a diffusion pump is switched on or before the valve on top of a diffusion pump is opened a quantitative leak test should be performed by observing the pressure rise in the respective locked section / subsection. The volumes of the various sections are given in chapter 2.1.

* The valve on top of a diffusion pump should be opened only if

  a) the diffusion pump is "ready for operation" (yelloy LED at the right hand side of the diffusion pump symbol),

  b) the roughing valve (V41, V10, V11) is closed,

  c) the pressure above the valve is lower than 0.1 mbars (LEDs F1, F2, F6 green), and,

  d) the backing up pressures (F15; F7, F8; F9, F10; F11, F12; F13, F14) remain good.

* Before the attempt is made to open one of the flat valves V1, V2, (V3a and V3b) or one of the flap valves V42, V14, V16, V18, V20, it should be verified that the pressure difference across the valve does not exceed some ten mbars.

In case of trouble make sure if all connections and supplies are o.k., if the control panel is made active, if a prevention by the hardware interlocking system exists, or if the VERRIEGELT LED is resetted.

5. Performance

During the test phase /3/, some minor changes appeared to be desirable:

* The originally adapted backing up diffusion pumps of 10 litres/s pumping speed each were not able to achieve a pressure ratio of < 1; they have been replaced by bigger ones as tabulated in chapter 2.1.

* R21 has been upgraded from 1.5 m^3/h to 4 m^3/h in order to improve the pressure between the two seals of the sliding tape.

* Likewise, R23, the backing up pump for the diffusion pump beneath the target chamber, has been converted from 1.5 m^3/h to 4 m^3/h capacity on account of the large gas desorption resulting from newly installed experimental equipment.

The overall reliability of the system, though satisfactory, has had to be improved with several respects:

* After longer periods of rest, the flap valves on top of the diffusion pumps may fail to open. In this case, they should be forced mechanically.

* With time an appreciable percentage of the thyristor relays failed to operate. This problem could be solved by clipping diodes which protect the control input of the thyristor relays.

* Two times a breakdown of the CAMAC power supply (by an operational mistake and by failure of a fuse) occured resulting in an unpredictable state of the CAMAC output registers, that means in an unsafe status of the vacuum system. In the future the DC voltages of the CAMAC crate will be surveilled in order to control the main power for Ü3 and Ü8 (see chapter 3.1).

* During a period of more than one year four spourious safety shut offs occured, probably caused by electical transients. Moreover some undesired safety shut offs were produced by flushing the target sluice for a period longer than five minutes.

* Only one failure of the heaters of the diffusion pumps occured. Some electronic components have been destroyed as a consequence of a short circuit of the main power supply.

The sliding seal of the target chamber works without any measurable pressure rise.

6. Final Remarks

It is quite obvious that future improvements of the vacuum system live from the experiences of the spectrograph users. All suggestions of this kind should be transferred to the authors of this report.

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