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A GUIDE TO WRITING MAINTENANCE, TEST AND CALIBRATION PROCEDURES

by a

CSNI Group of Experts
on Human Error Assessment

September 1981

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS
OECD NUCLEAR ENERGY AGENCY
38, boulevard Suchet, 75016 Paris, France

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The Nuclear Energy Agency (NEA) is a specialised Agency of the Organisation for Economic Co-operation and Development (OECD) in Paris. The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers who have responsibilities for nuclear safety research and nuclear licensing. The Committee was set up in 1973 to develop and co-ordinate the Nuclear Energy Agency's work in nuclear safety matters, replacing the former Committee on Reactor Safety Technology (CREST) with its more limited scope.

The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. This is done essentially by:

i) exchanging information about progress in safety research and regulatory matters in the different countries, and maintaining banks of specific data; these arrangements are of immediate benefit to the countries concerned;

ii) setting up working groups or task forces and arranging specialist meetings, in order to implement co-operation on specific subjects, and establishing international projects; the output of the study groups and meetings goes to enrich the data base available to national regulatory authorities and to the scientific community at large. If it reveals substantial gaps in knowledge or differences between national practices, the Committee may recommend that a unified approach be adopted to the problems involved. The aim here is to minimise differences and to achieve an international consensus wherever possible.

The main CSNI activities cover particular aspects of safety research relative to water reactors and fast reactors; probabilistic assessment and reliability analysis, especially with regard to rare events; siting research; fuel cycle safety research; various safety aspects of steel components in nuclear installations; and a number of specific exchanges of information.

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I. INTRODUCTION

The goal of this guide is to provide practical advice to those persons, typically engineers, who write maintenance, test and calibration procedures used in nuclear power plants. It is NOT a regulatory specification*.

Good layout of the documents supporting any procedure helps users to perform the task involved reliably and efficiently. However, procedures for routine maintenance, calibration and testing of equipment should not be presented in precisely the same way as operating procedures. More detail must be included, for instance, but not at the expense of clarity and conciseness. Greater reliability in executing these procedures can increase the reliability and availability of equipment involved, and may be important to maintaining adequate performance of highly reliable safety-related systems. A detailed examination of the clarity and completeness of the procedure documents used in a plant provides a good indication of the effort being put into maintaining and increasing operational safety of the plant.

The general principles underlying the design of routine procedures were discussed at a Workshop of the CSNI Group of Experts on Human Error Data and Assessment, which was held in Paris in April 1980. This guide collects together the ideas that were contributed at the Workshop, and has been critically reviewed and endorsed by the Group, comprising:

J. Rasmussen (1980 Chairman)	Risø National Laboratory, Denmark
H. Roggenbauer	Forschungszentrum Seibersdorf, Austria

* Current regulatory requirements in many countries are rather general. Detailed regulations have been in force in the Federal Republic of Germany since February 1978 [Sicherheitstechnische Regel des KTA, KTA 1201, 2/78; draft of amendment October 1979 (not yet in force)]. American National Standard ANSI N 18.7-1976 lays down requirements for administrative controls and quality assurance for operating nuclear power plants in the United States.

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W.E. Vesely Jr.	USNRC, United States
A.D. Swain	Sandia Laboratories, United States
G. Mancini	JRC - Ispra, Commission of the European Communities
M. Stephens (Secretary)	OECD Nuclear Energy Agency

Also incorporated are ideas contributed by the following persons who participated in the Workshop:

E. Bohr	TUV Rheinland, F.R. of Germany
Mr. Krotil	KWU, Federal Republic of Germany
Mr. Modemann	RWE, Federal Republic of Germany
K.D. Duncan	UWIST, United Kingdom
B.W. Eddershaw	ICI, United Kingdom

The recommendations given here are based on general human factors principles and studies of real plant incidents. Many of them may appear obvious - but they are no less important for all of that. Considerable discussion was required at the Workshop to arrive at a mutual understanding and consensus view on some points. There are differences between countries in the philosophy of what constitutes the optimum content and design of procedures. For instance, in one country it may be considered adequate to provide the procedure user with the complete set of elementary steps and a checklist, thus in principle rendering the procedure usable by almost anyone and essentially "good-proof". However another country which has a long tradition of catering to highly-trained craftsmen may consider it necessary to provide, in addition, sufficient information on the goals of the various phases of the procedure so that the user is able to understand the significance of the system response he observes. Another example is the use of specialised symbols and identification codes to identify actions and equipment, a practice which is used to varying degrees in different countries.

The 86 specific points given here constitute both a guide to preparing new procedures and a checklist for evaluating existing procedures with respect to good human factors practises. (Reference 5 is another checklist for procedure evaluation that covers several of the same points.)

Appendix II contains an example of a recently written procedure that incorporates many of the ideas presented here.

As evidenced by the references given on pp. 25-26, there are studies now in progress in several countries aimed at improving the documentation for procedures used in nuclear power stations. Hence while the guidance given here should definitely aid in improving currently common documentation practises, it most certainly does not constitute the last word that will be said on the subject.

A word on the terminology used in the guide

This guide addresses the problems involved in preparing the documentation needed for routine activities supporting the operation of a nuclear power station.

It is considered that a procedure is divided into several phases (e.g. system isolation, calibration, and restoration). Each phase will ordinarily consist of a group of steps which must be completed in a prescribed order. Each step consists of one (or a very few - See point 17 below) elementary actions.

II. PREPARING TO WRITE A PROCEDURE

II.1 Design Criteria

When designing procedure documents, one should keep several important factors in mind to avoid creating a procedure prone to incorrect execution:

1. What is the precise goal of the procedure?

   The purpose of the procedure and how it is to be executed should be completely and unambiguously recorded. This ensures that the goal has, in fact, been adequately specified, and the summary can later serve as a useful instructional aid to users.

2. Who is to use the procedure?

   While procedures should be written in unambiguous, consistent terms, even a "complete" description of the task inevitably assumes some foreknowledge on the part of the user. The qualifications (i.e. skills, knowledge and reading ability) of the least-qualified intended user will determine the level of detail that you should include, at least for those sections that may influence plant safety. Consider whether physical or organisational constraints will affect when, how or by whom the procedure will be performed.

3. How often will the procedure be executed by any given user?

   More detail may be necessary if the repeat frequency is low.

4. How many people are required to perform the procedure?

   If several people are involved, make it clear which person is responsible for overall co-ordination. If different versions of the procedure are to be written for the various persons involved, each version should incorporate a brief summary of the other person's actions, as well as the order in which they are to be carried out. (See Appendix II). The person in charge should have a complete version of the procedure.

5. How serious would the consequences of erroneous use be?

   If systems important to plant safety are involved, it may be wise to assess formally the impact that incorrect execution would have on system availability and reliability.

II.2 Sources of Information

When drafting the procedure, it is useful to:

6. Consult potential users.

   It is valuable to compare your description to their conception of how the equipment involved functions. Users will often be able to advise you on whether the proposed procedure is practical, and they will be less tempted to deviate from a procedure if they have helped to design it. They may point out errors in design, or ways of simplifying the procedure. However, if they are very familiar with the system(s) concerned, they may take for granted certain details of the task that should be included for completeness.

7. Consult the equipment manufacturer, if feasible.

   The manufacturer can provide instructions manuals for equipment use and service and confirm that correct equipment characteristics have been used, that the goal of the procedure is appropriate, and that the logic of the procedure steps is coherent.

III. DRAFTING THE STEP SEQUENCE

III.1 Structure

8. Decide what depth of detail is required in the procedure as a whole.

   In principle, procedures should be so easy to understand that no additional information is needed. In practice, the depth of detail to be included - at least for steps influencing safety - could be decided by evaluating the significance (i.e. consequence times its probability) of failure to perform each elementary step correctly. Alternatively, you could consider the minimum skill level that can be expected of the least qualified user. (See point 2)

9. Structure the procedure on two levels:

   (i) Use headings giving the goals of each phase of the procedure (e.g. "Isolate Safety Injection Signal Train 3");

   (ii) Under each heading, give the corresponding series of elementary steps to be done.

   Both experienced and apprentice users will thus have a clear picture of the logic underlying the sequence of elementary steps. Out-of-place, inaccurate or missing steps will be more apparent, thus making procedure design and verification more reliable.

10. Write all the steps in the order in which they are to be executed.

    Do not make the user refer to steps or pages out of sequence.

11. Where possible, group together operations that are all to be performed at one location.

12. If possible, link important steps to other actions which have immediately apparent consequences if omitted.

    The user can easily and inadvertently omit steps which are functionally only weakly related to the primary goal of the procedure (e.g. a check of standby channels before a circuit is isolated for testing). Equipment redesign may be called for to ensure a positive system response to manipulation. Redundancy in system response helps the user to verify that steps have been completed correctly.

13. Avoid referring to other procedures. If you do refer to other documents, be <u>precise</u> in identifying the portion to be consulted.

    If another procedure is not readily accessible, it will likely not be used.

III.2 <u>Content</u>

14. Be consistent as regards depth of detail in describing actions to be performed.

15. Use the simplest, fewest number of words necessary to specify precisely the action(s) to be performed in each step.

    Do not rely on the user's long term memory to supply "obvious" missing detail.

16. Each action should consist of a short, simple, affirmative verb in the active voice.

    Avoid negative forms, passive voice or converting verbs into abstract nouns. (e.g. Don't direct that, "Rotation of Knob A should not be continued after the indicator lamp B is extinguished". Rather, tell the user to "Rotate Knob A until indicator lamp B goes out").

17. Try to include only one action in each step.

    Some experts feel that up to three actions can satisfactorily be combined in one step <u>if</u> they are tightly related. (e.g. "Turn switch A to position 5, observe value on level indicator B and record the value" comprises three actions.) If you do sometimes include more than one action per step, then even so on average there should be less than about 1.5 actions per step over the whole procedure. (Appendix I gives one way to measure step complexity).

18. Clearly distinguish between actions to be performed and system responses (feedback) to be checked.

19. If an action will not lead to any immediately observable equipment response, state the delay time.

20. Make the user record instrument readings and calculated values.

    Do not have him rely on his short-term memory to retain the information for later use.

21. Minimise any calculation required. Where possible, replace calculation by including tables, graphs or charts.

22. If hand calculation cannot be avoided, have the complete formula to be used preprinted, including the dimensions of the input data:

$$\text{e.g.} \quad R\ (m\Omega) = \frac{U(V)}{J(KA)}$$

    The dimensions should correspond to those of the measurements taken. There should be enough space on the form set aside for recording the input data, the calculation and result, and an independent check re-calculation.

23. Warnings should be unambiguous, easy to understand and as extensive as necessary.

    However, explanatory notes and comments should be kept to the necessary minimum. A procedure is not a technical manual. Of course, a maintenance procedure will need to provide more detail than a test or calibration procedure.

24. State precautions or explanations pertinent to one or several steps immediately before the step(s).

25. Explain the reason for any imperative words (like "shall" or "must") that you use.

26. Include clear directions about necessary communication during execution, and specify which person is to perform each step.

    Such communication may include, e.g., reporting of results that affect the following steps to be done, instructions to wait while another person carries out the next part of the procedure, or confirmation that a phase of the procedure has been completed.

27. Instruct the user to inform the control room when the procedure has been started and when it has been completed.

    The control room operators must know when important equipment may be unavailable.

28. Decide on what type of checkoff will be sufficient to confirm that all steps and groups of steps have been successfully completed.

It may be adequate just to have the user sign off at the end of the procedure. However, it may be wise instead to have the person check off each group of steps (or even each step), depending on their importance and what feedback the user has from the system. Self-verification is important; equipment should be designed as far as possibl possible to respond positively and unambiguously to user actions.

A second person should check that important actions are completed correctly. For instance have any vital or complex calculation verified and signed off by a second person. If the procedure ends with important steps (e.g. restoration of switches and valves to service status), have a second person verify the status of the equipment and check off that the steps have been completed. (Steps near the end of a procedure are particularly vulnerable to omission).

Avoid insisting on verification of everything by a second person because the procedure could easily become cumbersome, obviously unnecessarily, and unpopular to perform. Users may be tempted to take less care in executing it if they know that all they do will be checked.

III.3 Step Layout

29. Be consistent in your layout of the procedure steps.

30. Number each individual step and number the steps consecutively.

Do not create sub-steps. Steps can easily be referred to by their serial number. If you add steps when revising a procedure, renumber all the steps consecutively.

31. Write the procedure in the form of a list, and in columns rather than paragraphs.

The list form gives a procedure a clear horizontal structure, thus taking into consideration that the user works through each step in the step sequence from left to right.

The column format is simpler to follow than the paragraph. The user can find his place again more easily after an interruption. He is more likely to notice omitted information. You can easily incorporate a checklist if you wish, and space to record data (see the following point).

32. Include space in the columns for:

- step number
- checkoff mark (see point 33)
- the action(s) to be performed (see point 17)
- where the user will observe system response
- the normal system response (including, for readings, quantitative limits of acceptability) (see point 40)
- system setpoints and, if adjustments are required, recording of the as-left condition of the system
- recording of readings, quantitative limits of an acceptable result, and any hand calculations (see point 22)
- abnormal system response
- what the user should do if he obtains an abnormal system response, unacceptable reading or result of calculations
- user comments.

33. If you include a checkoff column (rather than a separate checklist), put it beside the step number column.

After the procedure has been completed, any checking to identify possibly omitted steps will be simpler.

34. If you provide a separate column for drawings, photographs and notes, put it in the same position on each page.

35. Ensure that any codes and abbreviations you use to identify equipment are understandable, unique and consistently used.

36. Ensure that words have the same meaning whether in capital or small letters.

37. Be sure that references to equipment correspond <u>exactly</u> to the labels on them (including being abbreviated, with capital or small letters, arabic or roman numerals, etc.).

38. Identify the specific pieces of equipment to be manipulated in each step. Do not refer to an identification in a previous step.

For instance, specify both name and identification code of valves (e.g. "Close isolation valve IV-01").

39. Specify limits and expected values of readings quantitatively, rather than by giving relatively ambiguous references such as, e.g. "initial rate" or "minimum value".

Appendix I gives one way to measure the specificity of the steps in a procedure (i.e. the degree to which points 15, and 35 to 39 are respected).

40. Give the limits of acceptability for equipment readings expected to lie in a range. For example, if a reading should lie between 2.0 and 3.0, state these limits as: "2.0 to 3.0" (or in the format of step S18 of the procedure in Appendix II), rather than as "2.5 ± 0.5" or "2.5 ± 20%".

41. Clearly state if a calibration is to be performed with an increasing or decreasing input.

42. If specially controlled or calibrated test equipment is used, have the user record the test equipment serial number.

This allows re-verification of system operability if the test equipment used is later found to be faulty or miscalibrated.

43. Write mathematical expressions in such a form that correction factors are positive (if it is possible to do so).

Calculations involving negative factors are prone to error.

IV. COMPLETING THE MASTER VERSION

IV.1 Overall Layout

44. Include the following items on the first page(s) of the procedure:

- power plant and unit identification
- procedure title, number and revision number
- a place for the signature of the person authorising use of the procedure
- date of last review and of next scheduled review of the procedure
- list of modifications made in the procedure following previous reviews
- if the procedure is for temporary use, the date or conditions of expiry
- a table of contents
- a summary statement of the goal/function of the procedure
- explicit identification of the equipment to be worked on, and its location (room and place in the room)
- frequency with which the procedure is to be repeated (if periodic)
- prerequisite plant, system, or equipment conditions
- other actions or procedures to be completed before the procedure is used
- number and qualifications of users required, and where they are to be when performing the procedure
- precautions to be taken when the procedure is performed
- other reference documents needed
- a list of equipment and tools needed.

45. Begin the procedure with a schematic diagram of the system worked on, preferably simplified to the essential details.

    An algorithm of the logic of the procedure can usefully be placed here as well.

46. Provide a heading for each phase of the procedure to structure the procedure as a whole (see Appendix II).

47. Identify the headings by, e.g., a decimal classification scheme (i.e. 1, 1.1, 1.1.1). Keep the number of heading levels to a minimum, and not more than three. (The example procedure in Appendix II uses a one-level alphabetic identification scheme).

48. Include additional schematic diagrams, drawings or photographs in the procedure itself if they succinctly clarify system details or the action(s) to be performed in a step or group of steps.

The diagrams should be as simplified as possible and as close as possible to the step(s) concerned in the procedure. A fold-out from a left-hand page can be referred to conveniently as following pages are turned.

49. Repeat the procedure title, revision number and revision date on each page of the procedure.

50. Number pages as, e.g., "page 5 of 10" or "5/10".

51. Be sure that page numbers (taking into account the procedure number and revision number) are unique.

52. Begin each major phase of the procedure on a new page.

53. If a long group of steps extends over more than one page, repeat the group heading at the top of each new page of the list, along with the notation "(continued)".

54. Include a notation such as "END OF PROCEDURE" after the last procedure step as an indication that a complete version of the procedure instructions has been used.

The last page of the procedure is the one most vulnerable to easily unnoticed loss.

IV.2 Format

General

55. Prepare the final draft of the procedure on forms having a preprinted frame in which the procedure (and all results from its later use) must be written. (See Appendix II)

This will ensure consistent layout and that no information is lost when pages are reproduced or holes punched in them for storage in a binder. It is pleasing to the eye if a page has wider bottom than top margins.

56. Indicate the relative importance of different information in the procedure by using different type sizes or type faces, indenting, underlining, frames, or lines in the margin.

    Spacing out words is less effective. Capital letters stand out, but the eye tires rapidly of reading them, so they should be used sparingly.
    Consistent use of a few (about three) type styles can give effective variable emphasis, but use of more will likely be confusing.
    Coloured printing, used sparingly, can give impact to important information.

57. If the procedure is to be printed, ask the printer to use at least "10 point" type, with "1 to 2 point leading".

58. If the procedure is to be reproduced from a typewritten master version, use Pica or Elite (sic) type style.

59. If different versions of a procedure are produced for members of a team using a multi-person procedure, in each version, print the portion(s) to be performed by the other users in a distinctive type face.

Procedure Steps

60. For each step, ensure that the entries in the different columns are all written on the same baseline.

61. Be sure that any exponents or subscripts not on the baseline are clearly recognizable.

62. If possible, limit column width to seven words.

    The eye can easily scan this many words, so the user can read the line rapidly without information loss.

63. Indicate where a reading or computed value is to be recorded (e.g. by drawing a horizontal arrow from a "system response" column to the appropriate column. (See Appendix II)

64. Use one-and-a-half line spacing between steps, and a larger gap to separate groups of steps.

Tables and Lists

65. Divide the lines of data into groups, and include no more than five lines per group.

Increase the spacing between the groups, or draw a horizontal stroke between them.

66. If possible, limit the gap between columns in lists and tables to less than ½" (or 5 spaces). If this is not possible, increase the spacing between lines, or use horizontal strokes to link the columns.

Narrative Material

67. Limit the width of lines of any narrative material to about 65 letters, or break the lines into two columns. Divide the text into short paragraphs, headings, sub-headings, sections and paragraphs.

Drawings

68. If you include drawings, be sure that:

- they are really useful and necessary
- each has a unique caption
- accepted standards for good engineering drawings are respected
- if photo-reduction would render a detailed engineering drawing illegibly small, either it is reproduced full size (in a fold-out, if necessary) or a simpler version is drafted to be reduced
- if a line drawing is to be reduced, the lines and text remain legible.

Graphs

69. If you include graphs, be sure that:

- the lines on the graph paper are clearly reproducible on the copying machine to be used
- handwritten letters and numbers are well-formed and that typewritten characters are unbroken and unfilled
- in the final version, letters and numbers will be at least 3mm (1/8") high
- the scales are compatible with the divisions on the graph paper (to avoid the need for approximate interpolation).

V. CHECKING A NEW OR REVISED PROCEDURE

70. Check that the step sequence is coherent, accurate, complete, efficient and has no unwanted redundancy.

71. Check that steps are simple (i.e. essentially contain one action each - See point 17), and that actions and equipment are unambiguously described.

    Appendix I gives indexes for measuring step complexity and specificity. Other measures could be used equally well.

72. Be sure that there is unambiguous system feedback indicating completion of each step, along with cues that the next step is to be begun.

73. Check that the procedure includes all information the user will need, e.g.:

    - reference setpoints
    - identification codes
    - specific instructions on how to check system status
    - clear instructions on what the user should do if an emergency occurs while he is executing the procedure
    - at the end, a list of any follow-up actions he is to take after completing the procedure (e.g. a test or calibration following maintenance; notification of the control room that the procedure has been completed).

74. Be sure to check that numerical values included are correct.

    When checking texts one often concentrates on the words but not the numbers used.

75. Consider who will review the outcome of the procedure and what information he will need.

    Adequate and unambiguous data must be recorded during execution for the needs of the person assessing the results (and for the plant archives).

76. Have a prospective user do a "walk-through" test execution of the procedure in your presence. This is vital to ensuring that the procedure is accurate, complete, coherent and practical.

There are two practical constraints on this. Before reactor startup, there may be little consequence to executing a faulty procedure, but it may be difficult to set up realistic test conditions and system status. When the reactor is operating, one must avoid jeopardising plant safety by performing still unproven procedures. If an actual test execution is not possible, have a prospective user simulate performing it on on the spot.

VI. PREPARING USER COPIES

VI.1 Reproduction

77. Have procedures reproduced on good quality sturdy matte paper of a standard size, preferably on one side only using a simple, clear typeface.

78. Ensure that photographs, drawings and graphs have been clearly reproduced.

79. Beware of degradation in legibility from handling or repeated generations of reproduction.

VI.2 Storage

80. If you store procedures in looseleaf binders, group them into appropriate sections with an index leading off each section. Set off the start of each section with an index tab projecting beyond the right hand margin of the pages. Provide a unique title on the spine of each binder. Limit the contents of each binder to about 200 pages.

VII. ENCOURAGING ERROR-FREE USE OF PROCEDURES

81. Be sure that users are briefed on how to execute the procedure, in particular that they should:

- check off steps (or groups of steps) immediately after completing them and <u>before</u> starting the next (c.f. point 28)

- not "improve" the procedure or reorder the steps for convenience.

Changing the way a procedure is carried out can make secondary effects more significant (e.g. adding instrument recorders may load signal sources; substitute materials or equipment may seem at first to be "close enough" to that specified in the procedure, but there may be subtle, unacceptable differences).

- take extra care if they are interrupted while executing a procedure, and not try to remember a result until they can record it later. When they resume execution, they should verify that all the steps completed have been checked off, because it is easy to forget one's place when resuming the procedure.

82. Have the users record selected system responses (quantitative if possible) that are characteristic of the expected system behaviour when the procedure is performed correctly. Keep an up-to-date record of these parameter values in successive executions.

Changes in these measures may point up faulty execution, or that system behaviour is evolving and calls for revision of the procedure.

83. If the procedure is usually performed by one person, occasionally have a second person observe him execute it.

The observer may be able to rectify immediately a lack of understanding and thus prepare the user to perform better next time. He can also identify errors or ambiguities in the procedure needing correction.

84. Encourage discipline in applying systematic document control, specifically:

- return of procedures after use to avoid obsolete versions being used inadvertantly. Return of a procedure should be signed off on the work permit authorising the job
- a formal review procedure that will incorporate user experience
- when a procedure is retired, retirement of its number as well (rather than re-assignment to another procedure); this will cut down errors in cross-referencing procedures and in tracing previous use of them.

85. Keep procedures up to date

This is vital. Users will shun using obsolete, faulty procedures. Handwritten changes to correct outdated procedures often cause user uncertainty and incorrect execution. Whoever assesses the results of procedure use should analyze any handwritten notes to see if they indicate a need to modify the procedure. If possible, have equipment and procedures cross-referenced so that all procedures affected by plant evolution, e.g. equipment modifications or changes in reference setpoints can be quickly identified. All procedures should be reviewed periodically (ANSI N18.7-1976 suggests every two years) and revised if necessary. Keep the delay in issuing revisions as short as possible.

86. Be consistent in the structure and layout of all the written procedures used in your plant.

Try to see that tendencies of different procedure writers to more or less adequate description are evened out. Incorporate user experience into the norm for procedure layout. If these steps are taken, training will be more straightforward and standardised.

VIII. AFTERWORD

Error-free execution of procedures depends on more than the documentation principles described in the preceding chapters. Just as important are the conception of the whole work situation itself, user training, staff and work organisation and ergonomic design of equipment. Task execution is strongly affected by such simple things as poor or missing equipment labels, glare from unshielded illumination, proximity and comfortable height of instruments and controls, and having a place to put down the procedure documents while performing the required manipulations. Recent studies by EPRI (Refs. 11, 12 and 13) have brought into sharp focus the general principles involved here as they relate to power plant situations.

Such questions are beyond the scope of this booklet and only a detailed task analysis can identify all the important factors involved in each specific case.

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APPENDIX I

EXAMPLE MEASURES OF STEP COMPLEXITY AND SPECIFICITY*

COMPLEXITY INDEX (CI)

$$CI = \frac{\text{Number of actions in a sample of steps}^{+} \text{ in the procedure}}{\text{Number of steps}^{+} \text{ sampled}}$$

1. The number of actions is the number of verbs (or compound verbs) in a step.
2. Take a sample of 20% of the steps, but if there are less than 50 steps, use them all.
3. CI should be 1.5 or less.

SPECIFICITY INDEX (SI)

$$SI = \frac{\text{Number of steps in a sample that meet all 3 specificity criteria}}{\text{Number of steps sampled}}$$

1. The 3 specificity criteria are:
   A. Each action to be taken is specifically identified (e.g. open, close, torque, etc.)
   B. Limits (if applicable) are expressed quantitatively (e.g. 2 turns, 100 cm-N, etc.)
   C. Equipment or parts are identified completely (e.g. HPCI pump discharge bypass valve, HPCI-MO-17, etc.)
2. Take a sample of 20% of the steps, but if there are less than 50 steps use at least 10 of them.
3. SI should be at least .9.

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*Source: Reference 5

+or paragraph(s) for narrative material.

APPENDIX II

MODEL PROCEDURE+ DERIVED FROM THE VIEWS OF THE OPERATORS AT THE BUGEY POWER STATION, FRANCE

Following is a recently redesigned procedure being studied for possible introduction at the Bugey power station. The procedure is executed by two persons, one in the control room and one at the pump under test in the nuclear auxiliaries building. The person in the control room directs execution of the procedure, using the 8-page set of instructions on pages 37 to 44. The second person has his own 3-page set of instructions, given on pages 45 to 47.

+ Translated for this guide from the original version in French with the permission of EdF.

Note: The original version identifies systems, annunciator labels, etc. in abbreviated French technical terms. Rather than inventing equivalent English expressions, the original abbreviations have been used.

Glossary of French Terms and Abbreviations Used

AA : verrine d'alarme (annunciator)

APG : eau alimentaire - purge générateur de vapeur (steam generator purge system)

ASG : alimentation de secours des générateurs de vapeur (auxiliary steam generator feedwater system)

ARRIER : arrière (after)

AVT : avant (before)

BA : bâche (storage tank)

BAN : bâtiment des auxiliaires nucléaires (nuclear auxiliaries building)

BUTEE : butée (thrust)

C.O.A. : côté opposé à l'accouplement (opposite side from coupling)

CA : côté de l'accouplement (coupling side)

CC : commutateur (selector switch)

C25 : procédure de conduite n° 25 (operating procedure No.25)

CONTRE : contre (against)

DEB : débit (flow)

DECL : déclenché (disengaged)

ENCL : enclenché (engaged)

EP : essai périodique (periodic test)

ET : et (and)

FIN : fin (end)

GV : générateur de vapeur (steam generator)

ID : indicateur (indicator)

KIT	:	système informatisé d'acquisition de données (data collection computer)
LA	:	lampe (lamp)
LD	:	indicateur local de débit (local flow indicator)
LOCAL	:	local (location of equipment being tested)
LP	:	indicateur local de pression (local pressure indicator)
L1, L2, etc.	:	opération n° 1 en local, n° 2, etc. (operation No.1 at the equipment location, No. 2, etc.)
mCE	:	mètres de colonne d'eau (height of water in meters)
MO	:	moteur (motor)
MT	:	mesure de température (temperature measurement)
MULTI	:	multiplicateur (gearbox)
NON	:	non (not)
OUV	:	ouvert (open)
PAL, PALIER	:	palier (bearing)
PDR	:	panneau de repli (backup control panel)
PO	:	pompe (pump)
RAZ	:	retour à zéro (return to zero)
RC, RCM	:	relais de commande à main (manual control selector)
REGLANTE	:	réglante (regulating)
RF	:	réfrigérant (coolant)
SdC	:	salle de commande (control room)
SEB	:	système d'eau brute (intake water system)
SECOURS	:	secours (auxiliary, stand-by, emergency)
SYNOPTIQUE	:	panneau avec affichage schématique du fonctionnement de la tranche (schematic display of plant status)
S1, S2, etc.	:	opération n° 1 en salle de commande, n° 2, etc. (operation No. 1 in control room, No. 2, etc.)
TEMP	:	température

TO : touche (pushbutton)

TL : touche lumineuse (illuminated pushbutton)

VD : vanne d'eau déminéralisée (demineralised water valve)

VE : vanne d'eau (water valve)

VP : vanne haute pression (high pressure valve)

Symbols used in the procedure

(A) Identification label for a phase of the procedure

➧ "Perform" the following action"

◉ "Verify that the following condition is fulfilled".

I - OBJECT OF THE TEST

- Verify that Pump Unit ASG(Train A) functions normally and responds properly to a start-up order from the control room
- Verifythat the associated regulating valves are available and respond properly to an order to open Train A.

II - PRECONDITIONS FOR EXECUTING THE PROCEDURE

a - Withdrawal of the ASG circuit from service: Obtain the approval of the Shift Leader.

b - Unit Status: On power (% unimportant), ASG not in use.

c - Procedure instructions: For person in **SdC** (8 pages) and in **BAN** (3 pages).

d - Equipment: Vibration monitor to be used at the location of the ASG pump.

III - PARTICULAR CONDITIONS

! IF these conditions are not fulfilled, DO NOT DO THE TEST

• Tank ASG Ø1 BA full	(ASG 011 ID)
• Water temperature < 40° C	(no alarm ASG 020 AA)
• No alarm "FILL NEEDED"	(ASG 414 AA)

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	S d C	PAGE 2/8
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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
	(A) - *CIRCUIT ALIGNMENT FOR TESTING*	**PDR**				
S 1	◉ Protection against improper orders	ASG 205 CC	"SdC"	☐	☐	
S 2	◉ Availability of the controls: "RAZ vannes ASG" - TRAIN A	501 CC	"SdC"	☐	☐	
	"RAZ vannes ASG" - TRAIN B	502 CC	"SdC"	☐	☐	
		LOCAL				
S 4	◉ Valve open at bottom of tank ASG 001 BA	001 VD	OPEN	☐	☐	
		SdC				
S 4	➡ Test annunciator lamps		LIT	☐	☐	
S 5	◉ Regulator valves open: ASG 012 VD	501 AA	DARK	☐	☐	
	ASG 014 VD	503 AA	DARK	☐	☐	
	ASG 016 VD	505 AA	DARK	☐	☐	
S 6	◉ Position of ASG test switch	203 CC	"NORM"	☐	☐	
S 7	➡ Deactivate order to close APG valves	APG 507 CC	"ASG-A"	☐	☐	
S 8	➡ Push selector switch APG-507 CC		DONE	☐	☐	
	◉ Deactivation order checked	507 LA	LIT	☐	☐	
S 9	➡ Set RCM of regulating valve ASG-012 VD to 0%	ASG 401 RC	DONE	☐	☐	
	◉ Valve remains completely open	501 AA	DARK	☐	☐	

No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
(A)	*CIRCUIT ALIGNMENT (continued)*					
S 10	Set RCM of regulating valve ASG 014 VD to 0%	ASG 405 RC	DONE	☐	☐	
	◉ Valve remains completely open	503 AA	DARK	☐	☐	
S 11	Set RCM of regulating valve ASG 016 VD to 0%	409 RC	DONE	☐	☐	
	◉ Valve remains completely open	505 AA	DARK	☐	☐	
!	WAIT UNTIL CIRCUIT ALIGNMENT IN THE BAN IS COMPLETED					
I. 1	◉ *Isolation valve upstream of 001 PO open*					
I. 2	◉ *Isolation valve of the zero flow line open*					
I. 3	◉ *Isolation valve upstream of the SEB coolers open*					
I. 4	◉ *Isolation valves downstream of the SEB coolers open: 001 RF*					
	002 RF					
	003 RF					
I. 5	◉ *Oil levels of the bearings*					

EP	C25	ASC	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	SdC	PAGE 4/8
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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
(B)	- *START-UP*					
S 12	Start up pump unit ASG 001 PO (Train A)	ASG 202 TL	DONE	☐	☐	
	◉ Pump unit flow in : GV1	401 ID	MOVED FROM ZERO	☐	☐	
	GV2	402 ID	MOVED FROM ZERO	☐	☐	
	GV3	403 ID	MOVED FROM ZERO	☐	☐	
S 13	Return the two trains to zero <u>simultaneously</u>	001 TO ET 002 TO	DONE	☐	☐	
	◉ Regulating valves closed : ASG 012 VD	401 ID	RETURNED TO ZERO	☐	☐	
		501 AA	LIT	☐	☐	
	ASG 014 VD	402 ID	RETURNED TO ZERO	☐	☐	
		503 AA	LIT	☐	☐	
	ASG 016 VD	403 ID	RETURNED TO ZERO	☐	☐	
		505 AA	LIT	☐	☐	
S 14	◉ Motor current ASG 001 MO	09 ID	20 A 45	☐	☐	
S 15	◉ Pump backpressure	05 ID	90 b	☐	☐	
S 16	◉ Pump unit indicator changed to red	SYNOPTIQUE	RED	☐	☐	
S 17	◉ "ASG 001 PO POMPE ENCL"	KIT	STARTED	☐	☐	
	"ASG 012 VD VANNE REGLANTE SECOURS GV1 NON OUV DEB"	—	CLOSED	☐	☐	
	"ASG 014 VD ———— GV2 ————"	—	CLOSED	☐	☐	
	"ASG 016 VD ———— GV3 ————"	—	CLOSED	☐	☐	

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TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES

S d C — PAGE 5/8

No	OPERATIONS	LOCATION	RESULT EXPECTED				NO	COMMENTS
	(B) - *START-UP (continued)*							
!	LET THE PUMP UNIT RUN FOR AT LEAST 15 MINUTES							
1.6	◉ *Noise and vibration levels of pump unit*							
1.7	◉ *Pump unit overheating*							
1.8	◉ *No leaks in circuit*							
	(C) - *MEASUREMENT OF OPERATING PARAMETERS*							
S18	◉ Measurements given on KIT:	KIT						
	"ASG 090 MT - TEMP PAL AUT 001 MO"	ASG 090 MT		°C	85	☐	☐	
	" 092 MT - TEMP PAL ARRIER 001 MO"	092 MT		°C	85	☐	☐	
	" 033 MT - TEMP PAL MULTI CA 001 MO"	033 MT		°C	100	☐	☐	
	" 039 MT - TEMP PAL MULTI CA 001 PO"	039 MT		°C	100	☐	☐	
	" 024 MT - TEMP PALIER 001 PO	024 MT		°C	85	☐	☐	
	" 027 MT - TEMP PALIER BUTEE 001 PO"	027 MT		°C	85	☐	☐	
	" 094 MT - TEMP STATOR 001 MO"	094 MT		°C	120	☐	☐	
	" 030 MT - TEMP CONTRE BUTEE 001 PO"	030 MT		°C	85	☐	☐	
	" 035 MT - TEMP PAL MULTI C.O.A 001 MO"	035 MT		°C	100	☐	☐	
	" 037 MT - TEMP PAL MULTI C.O.A 001 PO"	037 MT		°C	100	☐	☐	

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	S d C	PAGE 6/8
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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
	(C) - *MEASUREMENT OF OPERATING PARAMETERS (continued)*					
!	WAIT UNTIL ALL READINGS HAVE BEEN TAKEN IN THE BAN					
1.9	◉ *Exterior pump vibration*	ASG 001 PO.				
1.10	◉ *Pump vibration on motor side*					
1.11	◉ *Motor vibration on pump side*					
1.12	◉ *Exterior motor vibration*					
1.13	◉ *Line flow at minimum flow*					
1.14	◉ *Pump suction pressure*					
	(D) - *STOP*					
S19	Stop pumc unit ASG 001 PO (TRAIN A)	ASG 202 TL	DONE	☐	☐	
	◉ Regulating valves completely open : : ASG 012 VD	501 AA	DARK	☐	☐	
	ASG 014 VD	503 AA	DARK	☐	☐	
	ASG 016 VD	505 AA	DARK	☐	☐	
	◉ Pump unit indicator changed to green	SYNOPTIQUE	GREEN	☐	☐	
	◉ "ASG 001 PO POMPE DECL"	KIT	STOP	☐	☐	
	"ASC 012 VD VANNE REGLANTE SECOURS GV1 NON OUV FIN"	—	OPEN	☐	☐	
	"ASG 014 VD ——— GV2 ———"	—	OPEN	☐	☐	
	"ASG 016 VD ——— GV3 ———"	—	OPEN	☐	☐	

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	S d C	PAGE 7/8
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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
	(E) - *RESTORATION OF CIRCUITS*					
S20	➧ Match RCM position with position of ASG 012 VD	ASG 401 RC	100 %	☐	☐	
S21	➧ Match RCM position with position of ASG 014 VD	405 RC	100 %	☐	☐	
S22	➧ Match RCM position with position of ASG 016 VD	409 RC	100 %	☐	☐	
S23	➧ Reactivate APG valve closure order	APG 507 CC	"N"	☐	☐	
	END OF TEST					

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	SdC	PAGE 8/8
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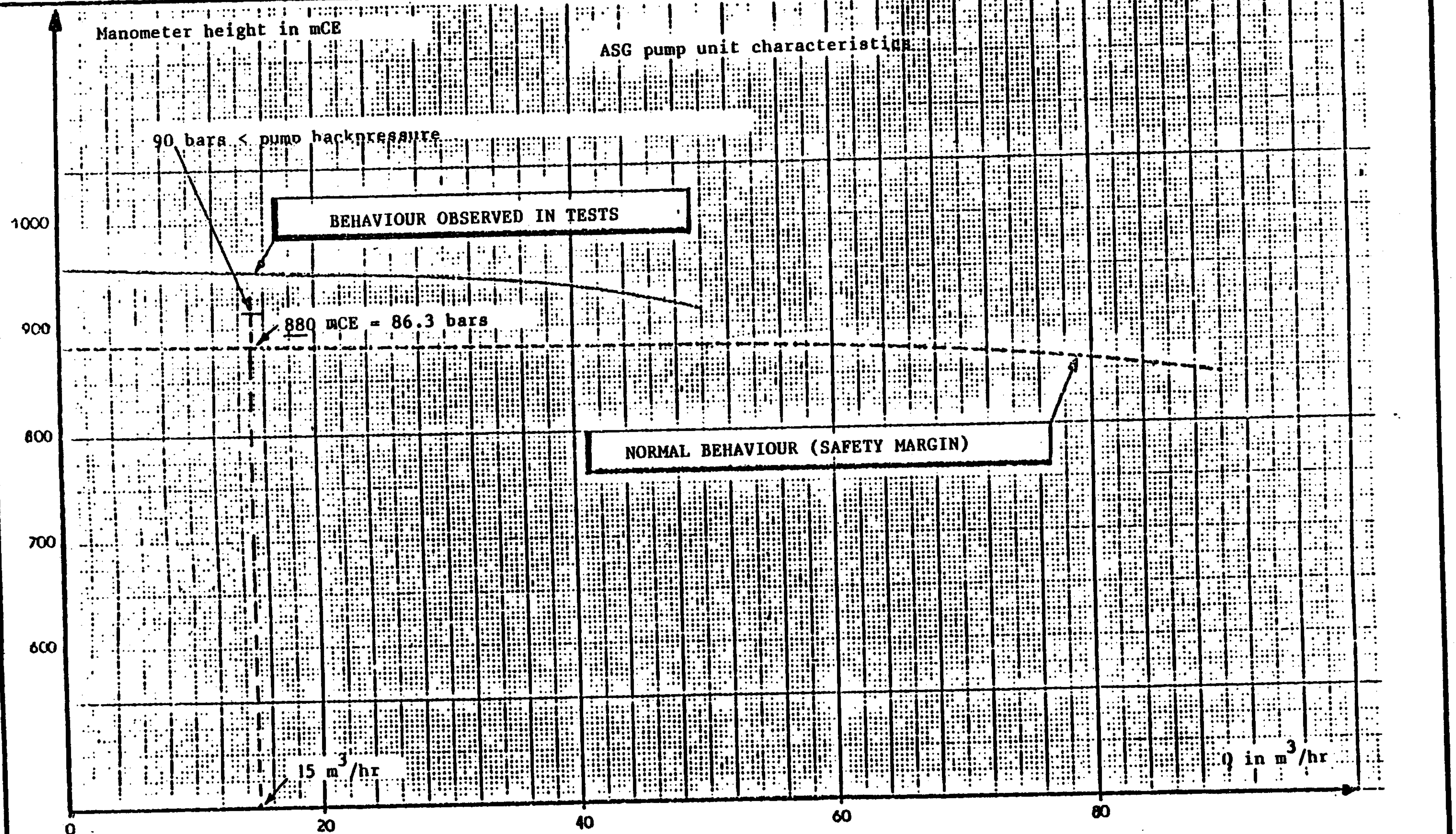

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	BAN	PAGE
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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
	Ⓐ *CIRCUIT ALIGNMENT*					
1. 1	◉ Isolation valve upstream of 001 PO open	ASG 003 VD	OPEN	☐	☐	
1. 2	◉ Isolation valve of the zero flow line open	116 VD	OPEN	☐	☐	
1. 3	◉ Isolation valve upstream of the SEB coolers open	SEB 271 VE	OPEN	☐	☐	
1. 4	◉ Isolation valves downstream of the SEB coolers open: 001 RF	275 VE	OPEN	☐	☐	
	002 RF	276 VE	OPEN	☐	☐	
	003 RF	273 VE	OPEN	☐	☐	
1. 5	◉ Bearing oil levels	ASG 001 PO	CORRECT	☐	☐	
!	SEND "CIRCUITS ALIGNED"					
	Ⓑ *START-UP* *Operations in SdC:* *start-up pump unit and close regulating valves*					
!	WAIT FOR PUMP UNIT ASG 001 PO TO START					
1. 6	◉ Noise and vibration levels	ASG 001 PO	NORMAL	☐	☐	
1. 7	◉ Overheating	———	NORMAL	☐	☐	
1. 8	◉ No leaks in the circuit	———	YES	☐	☐	
!	LET PUMP UNIT RUN FOR 15 MINUTES					

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No	OPERATIONS	LOCATION	RESULT EXPECTED	YES	NO	COMMENTS
	(C) - *MEASUREMENT OF OPERATING PARAMETERS*					
1.9	◉ Exterior pump vibration		10 µ	☐	☐	
1.10	◉ Pump vibration on motor side		12,5 µ	☐	☐	
1.11	◉ Motor vibration on pump side		12,5 µ	☐	☐	
1.12	◉ Exterior motor vibration		12,5 µ	☐	☐	
1.13	◉ Line flow at minimum flow	ASG 10 LD	15 m^3/h	☐	☐	
1.14	◉ Pump suction pressure	13 LP	1,5 b	☐	☐	
!	SEND "ALL READINGS TAKEN"					
	END OF TEST					

EP	C25	ASG	21	TEST OF THE OPERATION OF PUMP UNIT ASG 001 PO (TRAIN A) AND ASSOCIATED REGULATING VALVES	BAN	PAGE
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SIMPLIFIED PART OF ASG CIRCUIT RELATED TO ASG 001 PO