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Acceptance Tests of Computer Based Communication and Teleprocessing Systems: Objectives, Contents, Methods and Problems

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1 Objectives of the Acceptance Tests

The objective of the acceptance test phase of a project is to demonstrate to the customer that the system is ready to be delivered and that it satisfies the contract. «Ready to be delivered» means that the functional ability, the performance and the service reliability of the system have been fully achieved and that operation can begin. It means also that all the items specified in the contract are available in their definitive state. Among these we would mention the documentation on how to use, operate and maintain the system [2, 4, 5].

The introduction of a new system in an organisation can call for important changes in the structures and in the operational methods of the organisation itself. Extensive conversion may be necessary for the setting in operation of the new system. It can ask for a huge investment in manpower. In some cases it is no more possible to return to the old structure after starting system operation. All these points lead to significant risks for the customer's organisation and they too have serious financial consequences. The objective of the acceptance tests is to reduce these risks as much as possible.

2 The Scope and the Content of the Acceptance Tests

The acceptance tests should include the following items:

- the inventory control of the delivered products (hardware and software)
- the hardware tests
- the functions demonstration of the system (user and system oriented functions)
- the performance demonstration
- the reliability demonstration of the system
- the verification of the user and system documentation

The first activity is self-explanatory. The other ones merit detailed comments.

21 The Hardware Tests

This paper still limits investigations to the test problems of systems which are implemented with standard hardware. In this case the acceptance tests for the hardware are simpler to plan and to carry out than for the prototype. The bigger the number of known installations with similar equipment, the higher the probability that the delivered hardware will perform according to the specifications. The objective of the hardware tests, is to control the delivered unit as a «well manufactured» product. It is not to prove again that the equipment works well.

Nevertheless, standard units may also bring some surprises if they are used in an unusual configuration. We can mention the case of a front-end-computer in one of Swiss PTT's systems. The unit in question, already installed in many other systems, had sporadic failures. After long investigations it occured that the trouble was caused by a deficiency of the power supply, which could not support safely the large main storage configuration installed for the PTT front-end. The PTT units were the first in Europe to use actively the whole of the configured storage space.

The hardware tests are usually based on the execution of the maintenance programs provided by the vendor of the equipments. The test categories suggested are the following:

- execution of every field engineering test program for every unit of the system
- control of the correct functioning or of the availability of maintenance features (alarms, spare heads and tracks on mass storage units, etc.)
- control of the interfaces with the telecommunication equipments
- behaviour of the equipments operating at the limits of the environmental conditions (variations of climatic and electrical environments)

An important point in hardware acceptance tests is the timing of the tests. It is a generally accepted rule to carry out the hardware tests completely separately from the software tests. In addition, in order to test the functions of the system (i.e. the software) on fully proven equipments, it is recommended to execute the hardware tests at the very beginning of the acceptance phase.

It is advisable to keep statistics about the outages of the equipments as soon as they are installed (development or system test phase), in order to detect possible «black sheep» before the system is accepted and in operation. If units fail too often, the customer could condition the acceptance with their replacement. This point is particularly important if the customer himself intends to maintain the hardware.

22 The Functions Demonstration of the System

The objective of the functions demonstration is to control that all specified on-line and off-line functions are available and that they comply with the requirements.

The tests have not only to demonstrate that all functions work correctly under normal conditions and with normal data but also to prove that bad input data, incorrect operating, special events or hardware failures can be tolerated by the system according to the specified limits.

Particular attention has to be paid to the functions which support the reliability of the system. They are essential for on-line and real-time systems, especially for the ones assuming continuous service. Procedures for back-up switching or recovery are generally complex. Improvement after the cutover of the system may be very risky for the continuity of the service.

The functions for generating and initiating the system have also to be tested. They are vital to set the system in real operation. We find also in this category the demonstration of the maintenance functions, such as loading, unloading or reorganisation of the data base.

The statistics should not be forgotten. Different statistics produced will be used to measure the system performance during the performance demonstration. Tests within the functions demonstration have to assure that the results of the measurements are correct.

Test cases are prepared to check each function. They are grouped in test sets. A test set contains the test cases for one isolated function of a group of similar functions. *Figure 1* gives the coarse structure of a sample of test sets, which were executed during the acceptance of the TERCO system.

Functions tests are often executed in an isolated manner. Each function is tested independently in order to exclude interferences between functions. Such interferences may introduce difficulties in analysing the result. Thus, the first phase should be followed by a repetition of the tests with the aim to demonstrate a combination of several functions in parallel. This second phase should display no degradation as far as the quality of the functions is concerned. For this repetition of the functions demonstrations, the use of a traffic generator to simulate a background load for the system would be very useful. An alternative to the traffic generator can be the involvement of a test cell with real terminals and human operators producing the background traffic according to a defined script. This solution has the disadvantage to be less under control (i.e. the tests conditions are less reproducible) than a traffic generator.

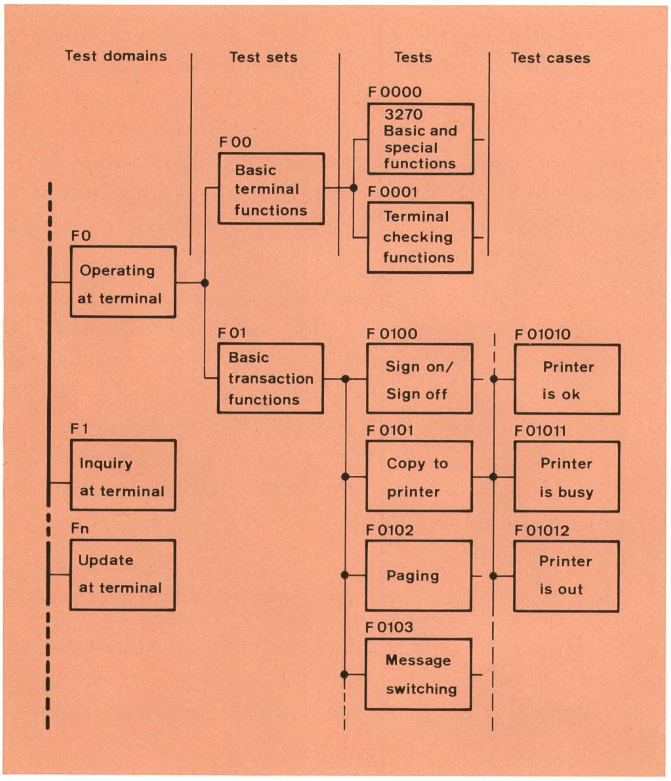

Fig. 1
Sample of the test structure for the acceptance of the TERCO system
F Group of functions which have to be tested

The execution of the demonstration in two phases, isolated and combined tests, is not always possible when considering the time available for the whole acceptance test phase. In this case, the combined demonstration should be preferred to the isolated acceptance tests. As a replacement for the first phase the customer should attend the isolated functions tests during the system test phase as an observer, and the contractor is asked to document the successful test results as a prerequisite to the beginning of the acceptance phase.

23 The Performance Demonstration of the System

The objective of the performance demonstration is to check that the system is able to process the traffic and the amount of information is according to the specifications and conditions defined in the requirements.

The performance of an on-line or real-time system are characterized by the following elements:

- *The throughput* is the quantity of information units (messages, transactions) that the system is able to process in a defined time (seconds, minutes, hours, etc.)
- *The response time* is the time period necessary to the system to receive, process and transmit an information unit. The definition of response time normally includes the transmission time in teleprocessing systems. Under this definition the response time is a performance measurement at the user terminal and is dependent not only on the data processing system but also on the data communications network.
  The response time is usually defined as the time between the start of the transmission of a message (e.g. the depression of the transmit key on a keyboard) and the indication of the reaction of the system (e.g. the display of the first character of the answer on a VDU or a printer).
- *The transit time* is used in connection with message switching or packet switching systems. It is defined as the time period between the receiving of the last character of an information unit and the sending of the first character of the processed information. The transit time is also named *system response time* and corresponds to the response time minus the transmission time.

Another element often belonging to the performance definition is the time a system needs to recover after a service interruption caused by a hardware or software failure. This figure may be defined as the time between a total breakdown and the restart of operations, or the switching time between the outage of a unit and the activation of a back-up unit.

Finally, a very different point which is not time related but which is an integral part of the performance definition of most teleprocessing systems, is the ability to store on-line the amount of data specified in the data base requirements.

Performance is usually sufficiently defined in terms of throughput and response time. This is the case for dedicated systems with a single application or if several applications are altogether implemented at the same time. If the intention is to implement other applications in a later phase, it may be necessary to define the maximum allowed loading of the system for the first application(s) in order to ensure spare system capacity for the future implementations. The loading of the system can be defined with additional performance parameters. The usual ones are:

- the load of the central processing unit (in %)
- the load of the channels (in %)
- the occupation of the main storage by resident programs (in % or kbytes)

The check of the performance is a significant element of the acceptance tests of on-line and real-time systems. An important part of the satisfaction level (or disappointment) experienced by the users of a teleprocessing system is conditioned by the performance. Bad response time in a telephone directory assistance system will irritate both the operator at the console and the waiting customer.

Many problems make performance testing look like a pretentious task:

- It is often very difficult to generate the effective peak traffic because the full load configuration with all terminals is not available at the time of the tests or because tests with the whole teleprocessing network are too costly from the manpower point of view. In most cases the personnel are simply not available: they are working in the old organization and cannot be released in sufficient number to create representative volume traffic for the tests. On the other hand, personnel may not be sufficiently trained on the new system at this time.
- The definition of the future traffic is sometimes inaccurate. The new system can modify the mode of operation of the organisation. The traffic is not a 1 to 1 copy of the existent situation.
- Real traffic is of statistical nature. The tests have to take this fact into account. On the other hand, the tests should be reproducible. Test methods have to cope with this situation. Accurate scripts must be prepared to execute the tests. But it should be possible to change easily the test parameters.
- The real data base is perhaps not available. The tests have to rely on a test data base. The structure of the real data has often an important influence on the final performance. The test data base may be inaccurate.

For the reasons mentioned above, the performance demonstration has often to be planned and executed on the basis of simulation. This is particularly true for large scale systems, for which volume testing can not be practically executed extensively without the help of traffic generators.

The customer has to bear this fact in mind when he negotiates the contract with the vendor. He should include a clause stipulating that the performance demonstration has to be executed with simulators delivered by the contractor, if it is evident from the very beginning that full scale volume tests will not be possible with real traffic, operators and terminals at the time of the acceptance tests. Such test accessories can cause higher project costs. However, this investment is useful not only for the acceptance of the system but also provides good services after the setting in operation in connection with maintenance activities like extensions of the teleprocessing network.

Overload tests are the last item to mention in relation with the performance demonstration. These tests have to demonstrate that the system is able to cope with an overload situation without serious service degradations like total breakdowns or lost or mutilated informations. The stability of the system during overload situation is not an intrinsic performance criterion, but the check of it may adequately be integrated in the performance demonstration, since it needs the same methods and tools to produce the high traffic volumes as the throughput tests.

24 The Reliability Demonstration of the System

Many computer systems have to fulfill hard reliability requirements. This is particularly true for teleprocessing or communications systems. The ATECO system with its triplex configuration *(Fig. 2)* was planned with the aim to allow only one total breakdown within five years of operation. The concept was sound from the hardware point of view. However, one can easily imagine the disillusionment of the PTT personnel, early in the development and test phases as soon as they understood, what software really was (it had a magic flavour up to that time!).

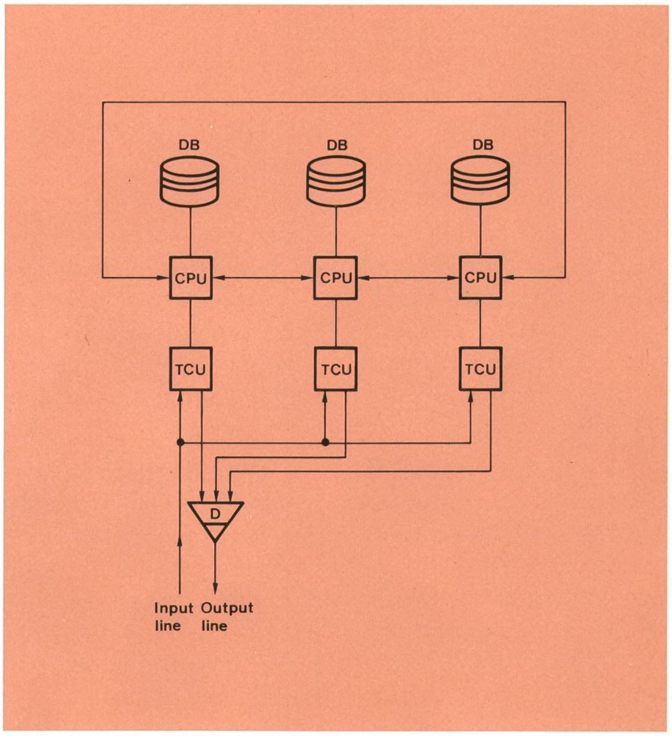

Fig. 2
Triplex configuration of the ATECO system
DB Massstorage for messages and routing information
CPU Central processing unit
TCU Telecommunication control unit
D Majority logic

Table I. Reliability requirements for the TERCO system

Type of failure		Telephone directory	Other applications
Outside causes (sabotage, act of god, etc.)	Maximal time System can be non-operational	15 min	4 h
	Restricted operations	Not allowed[1]	Not allowed
Technical troubles (HW/SW)	Maximal interruption allowed – daily	30 s [2]	30 s
	– monthly	5 min [2]	15 min
	– yearly	15 min [2]	4 h

[1] Two back-up centres required for every centre; for the directory applications, the back-up DB may operate 24 h out of date; updating should be possible within 4 h
[2] The DB has to be updated before restart of operations

The requirements for the TERCO system were not so demanding; nevertheless, they are very high too *Tab. I)*. They correspond to a yearly availability greater than 99,9 %. The solution is a computer network with centres configured with duplex installations *(Fig. 3)*. In case of failures the service is transferred automatically to an internal or external back-up system. The switching operation is executed within maximum 30 seconds and produces normally no interruption of service for the terminal user.

Such high reliability requirements ask for sophisticated and complex hardware and software implementations (redundant systems, special control software, etc.). They influence strongly the cost of the systems. It is, therefore, very important for the customer to know if the system meets really the specified reliability. It means simply that the reliability should also be tested.

This problem has two aspects: First, the contractor has to prove that all the features, designed and developed to achieve the required reliability, are working correctly. It means, for instance, the automatic mechanisms transfer the operations from a defective hardware to a back-up system. These tests have to be integrated in the functions demonstration.

Secondly, it should be demonstrated that the whole system, and within it especially the software, has reached a sufficient degree of maturity and stability. Bugs which could cause total breakdowns should be eliminated as far as possible. There are unfortunately no means to check it absolutely. A way to receive a feeling about it is to integrate a reliability demonstration in the acceptance phase.

The objective of the reliability demonstration is limited. It does not intend to verify that the reliability requirements are fully achieved. It has only to show that the system is able to work within a defined period of time without total breakdown or with the requirements specified for a time period equivalent to the duration of the demonstration. This test phase has to be executed with conditions as near as possible to life situations.

For the type of computer projects considered in this paper the achievement of the reliability requirements during one week (120 h = 5 days, or 168 h = 7 days) seems to be a reasonable and realistic criterion from the technical and management point of view. It is generally this figure which is required for the acceptance of the PTT systems.

One week is very short in the case of the ATECO project, by comparison with the initial objectives (five years without interruption of service). One should note that such a modest aim demands already considerable effort for the customer in terms of time and personnel ressources if the test is executed under near life conditions *(Fig. 4)*.

A possible complement to the reliability demonstration, in order to compensate its limitations, would be to condition the final acceptance by the accomplishment of the reliability requirements during a longer period with the system in real operation (e.g. the guarantee period). This solution may be difficult to negotiate with the contractor, or the related contract may be difficult to apply in practice because the system is not any more under the control of the contractor during this period. The PTT have striven for this approach for the TERCO system and have encountered the mentioned problems. The final solution to ensure the reliability requirements was an assistance contract with the vendor, signed after the formal acceptance of the system. An experimental service period of six months under near life conditions was organised under the terms of this assistance contract. The solution was not optimal for the PTT from a

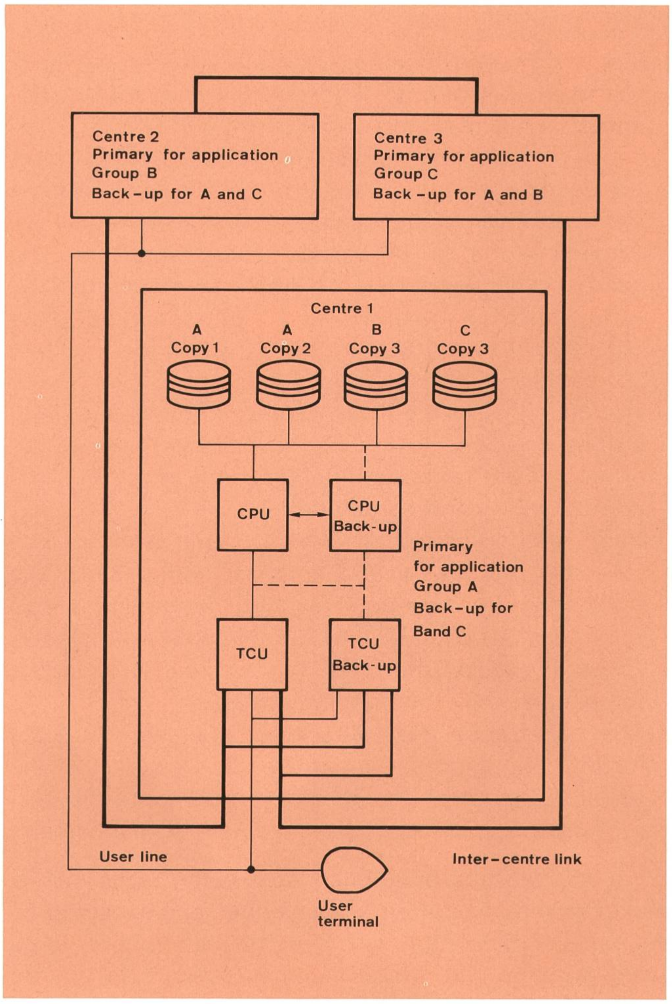

Fig. 3
Configuration of the computer network for the TERCO system
Centre internal or centre external switching of operations to back-up: <30 s
CPU Central processing unit
TCU Telecommunication control unit

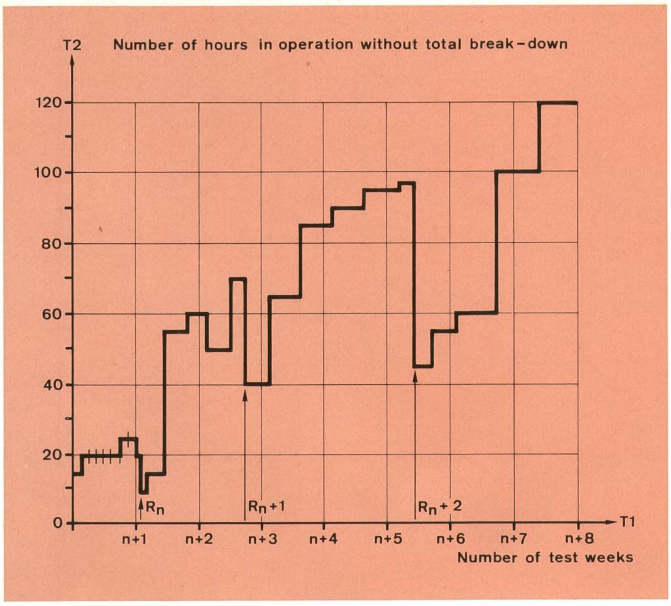

Fig. 4
Reliability tests with the ATECO system
T1 Duration of the test phase
T2 Achieved reliability between two break-downs
R Introduction of new SW-release

pure legal point of view because the system was already formally accepted and the position of the PTT was therefore weaker.

In practice this compromise was nevertheless a success since it allowed the PTT to set a system in service with a high degree of stability (the availability of the system for the users was 100 % during nine of the 12 months of the first year of operation).

25 The Verification of the Documentation

An objective of the acceptance phase is also to check that the documentation delivered by the contractor is available and sufficient to use, operate and maintain the system.

The acceptance tests have to rely on the documentation in its final state. Documentation activities are sometimes the first ones which are shifted to the end of the project cycle in case of manpower shortage. However, the availability of good and useful documentation is an important prerequisite for the customer to set the system in operation. The customer can protect himself against surprises if the complete documentation is available at the beginning of the acceptance phase.

A good means to test the usefulness and the accuracy of the documentation is to apply it when designing the tests scripts.

3 Planning Acceptance Tests

The acceptance tests have to be planned very early in the project. It is even advisable to have some commitments in the contract. At this time they can perhaps be only of very general nature. However, it is essential for the further planning to specify that the acceptance phase comprehends the three different demonstrations described under paragraph 2, or that the performance has to be demonstrated with the full throughput of the system.

The acceptance tests are laid out and formalized in a document called the acceptance test specification (or plan). This specification should be written in concert by the contractor and the customer.

A first version of the acceptance test specification should be prepared as early as possible in the project. It will be completed and cleared up in an iterative way between the two partners. The document has to be approved by the contractor and the customer before beginning of acceptance tests.

The acceptance test specification is often planned in parallel with the system test specification, since most test cases can be used for the two phases.

An important question is: how much time has to be assigned to the acceptance phase? There is no definite rule. Projects were reported to have as much as 30 % to 40 % of the time spent on acceptance testing [1]. In our opinion, with a serious and extensive system test phase and with an effective separation between the system test and the acceptance phases, as we recommend it, the figure should be about 10 to 15 %.

The total time planned for the TERCO project was 28 months. Three months were dedicated to the acceptance phase. The contract specified that the acceptance specification had to be submitted to the PTT for approval at least six months before the planned beginning of the acceptance phase. Six months were allocated by the contractor to the system test phase.

As another example, the *Figure 5* describes the planning evolution for the ATECO project. The large modifications in the planning estimations were the consequence of an initial underestimate of the time necessary to carry out the integration and system tests.

4 The Role of the Customer

There are two extreme possible approaches to the role of the customer in the acceptance phase:

- The customer plans, prepares and carries out the acceptance tests without the help and participation of the contractor.

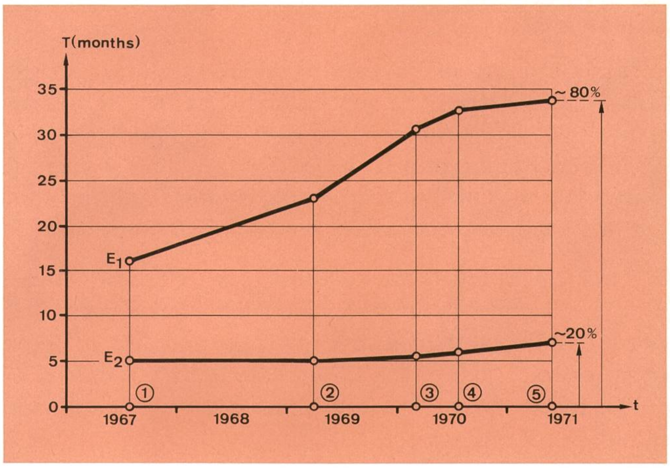

Fig. 5
Evolution of planning for the ATECO project
E1 Time estimation for coding, unit tests and integration tests
E2 Time estimation for system and acceptance tests
①...④ Successive time estimations
⑤ Effective achievement of the project

– The contractor plans and prepares the acceptance tests. The specification is approved by the customer. The tests are carried out by the contractor and have to be approved by the customer, who acts as observer during the tests.

The first approach gives full freedom to the customer to check the system according to his own criteria. It asks for an intensive engagement in manpower on the other hand.

The second approach limits the participation of the customer only to the approval of test specifications and results. He has no possibility to make his own investigations on the quality of the system. The manpower needed by the customer is minimized.

We think that the right approach lies in between. The customer should use the manpower of the contractor as far as possible. The acceptance tests should be specified in concert by the two partners. The tests should be carried out by the staff of the contractor with the help and under the leadership of the customer.

The contractor can try to get the final approval of the acceptance specification before starting the system test phase. This would ease his problems and investments, since in this case the systems tests and acceptance tests could be fully identical. It is recommended to reject this approach. In many cases the system test phase is the first occasion for the customer to visualize, as an observer of the tests, what his system will really look like. Some features of the system can appear more important for the service than estimated earlier and, therefore, necessitate more extensive demonstrations than in the first draft of the acceptance specification. It is advisable to delay the final approval nearly up to the middle of the system test phase.

The customer should also negotiate to have the freedom to realize some additional tests with his own personnel if it is necessary.

5 Organisation for the Test Phases

The test phases of large scale projects require participation of the customer's staff in all cases. This also applies to turnkey projects.

The involvement of the customer's staff is generally on two levels:

- firstly, manpower is needed to observe the system test and, secondly, to negotiate the guidelines, to specify or evaluate the tests, to analyze the results during the acceptance phase
- in addition, the contractor may require operators for the system and the terminals during all test phases

For the first level, the customer has to form his own test group that will be responsible for all activities. This group may consist of a test manager and two or three other people. Half of the group should be composed of EDP specialists and the other half of very experienced members of the users.

The manpower needed for the second level may be quantitatively much more important. A representative test cell for a large teleprocessing system needs between 10 to 50 terminals. Tens of people may be needed during many months to carry out the tests.

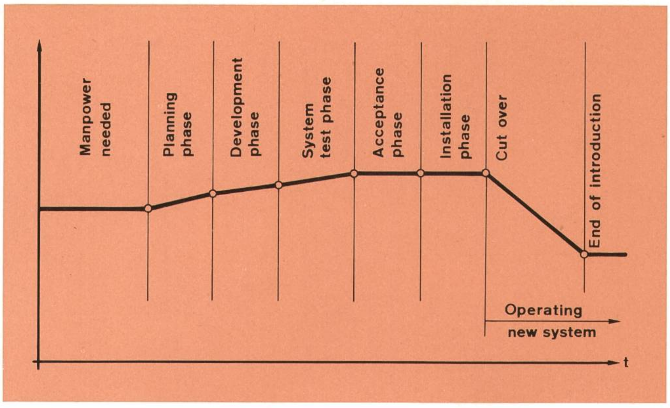

Fig. 6
Evolution of the manpower needed by customer

It is sometimes a difficult task for the project management of the customer to make his top management understand that a special manpower effort is needed to test the system before setting into operation. The task is even more difficult if the aim of the project is to rationalize the operations of the company (i.e. generally reduction of personnel) and if the project is implemented by an external contractor under a turnkey contract. It is a fact that even with the contractor's staff as large as possible for all phases of the project, the customer needs more manpower during the planning, development and installation phases of the system *(Fig. 6)*.

The integration of some of his staff in the test groups of the contractor may also be an interesting possibility for the customer to get a general overview of the test activities.

The involvement of the future operating team of the computer system in the test activities is also to be recommended. System and acceptance tests are perhaps the only possibility for the staff to be trained for the special procedures like recoveries or start up without risk.

6 The Test Documentation for the Acceptance Phase

Acceptance test asks for a special documentation effort. Each test has to be generally defined in the acceptance specification. In addition, a detailed script (or scenario) has to be prepared.

Three categories of documents can be identified:

- the acceptance test specification
- the test specification (detailed specification for each test)
- the test report (analysis of the test results)

Table II gives the outline of a test specification as used for the TERCO project.

The acquisition of a word processing system is a very useful tool to prepare the documentation since the acceptance documents have to be frequently updated before final approval.

7 Conditions for the Acceptance Phase

71 Prerequisites for the Start

A clear separation between system tests and acceptance tests is important. This point was already emphasized in an earlier paper [1].

Table II. Outline of specification for acceptance test (TERCO)

Test name

1. *Test outlines*
1.1 Test identification (No.)
1.2 Test definition:
- Objectives, assumptions
- References
- Success criteria

1.3 Needed test configuration
1.4 Needed test personnel

2. *Prerequisites for test execution*
2.1 Checklist primary centre
2.2 Checklist secondary centre
2.3 Checklist test cell

3. *Management of test data*

4. *Specifications of the test steps*

5. *Detailed scripts*
5.1 Scripts for system operators
5.2 Scripts for terminal operators

6. *Processing for automated results analysis*

7. *Test reports*
7.1 Report of centres
7.2 Report of test cell
7.3 Report manual results analysis
7.4 Report automated results analysis

Prerequisites are, therefore, necessary to assure that the system is really ready for acceptance. Some of them are listed below:

- all functions are implemented
- the documentation is available
- all system tests are successful
- all detected errors have been eliminated
- the system contains no temporary software patch

Another important requirement is to «freeze» the system during the acceptance phase. Any change or correction, which are possibly necessary to carry on with the tests, have to be approved by the customer and executed under his control.

72 Conditions for the Approval

In the most favourable (and generally hypothetical) case all tests will be successful and the system can be easily accepted. In real life, remaining errors will be detected. It is, therefore, necessary to specify a procedure to deal with this problem and to rule under which conditions the system can be accepted.

Some of the points to specify are the following:

- Which category of errors can be tolerated and treated as cases of guarantee after the acceptance of the system?
- Which errors have to be corrected before final acceptance?
- Which tests have to be repeated after correction of the errors?
- Which is the highest tolerated number of errors? If this number is exceeded all acceptance tests have to be repeated.

Such points have to be exactly specified in the acceptance specification. This is to avoid controversy between the customer and the contractor during the acceptance phase.

Another important point is to define as far as possible success criteria, which are quantitatively measurable or which may be clearly checked. Subjective or qualitative criteria are an evident source of misinterpretations and long discussions.

8 Participation of the Customer to other Tests than the Acceptance Tests

81 Participation to the System Test

The customer can participate with profit to the system test phase as an observer. This participation may be useful for both partners:

- System tests and acceptance tests have many common tests *(Fig. 7)*. The participation will help to train the test group of the customer.
- The customer can observe the progress of the project and evaluate himself if the system is really «ready for acceptance» at the end of the phase.
- The contractor can use the expertise of the customer's staff to define tests which correspond as nearly as possible to the real application condition.

82 User Tests

The customer should have the possibility of an early access to the system in order to train his staff to use and operate the new equipment.

These user tests can begin during the system test phase. The contract should mention that the customer is allowed to use the system a definite number of hours per day or per week during the project development.

The user tests may be a very useful contribution to the test of the system because it is a «quasi-life» source of traffic.

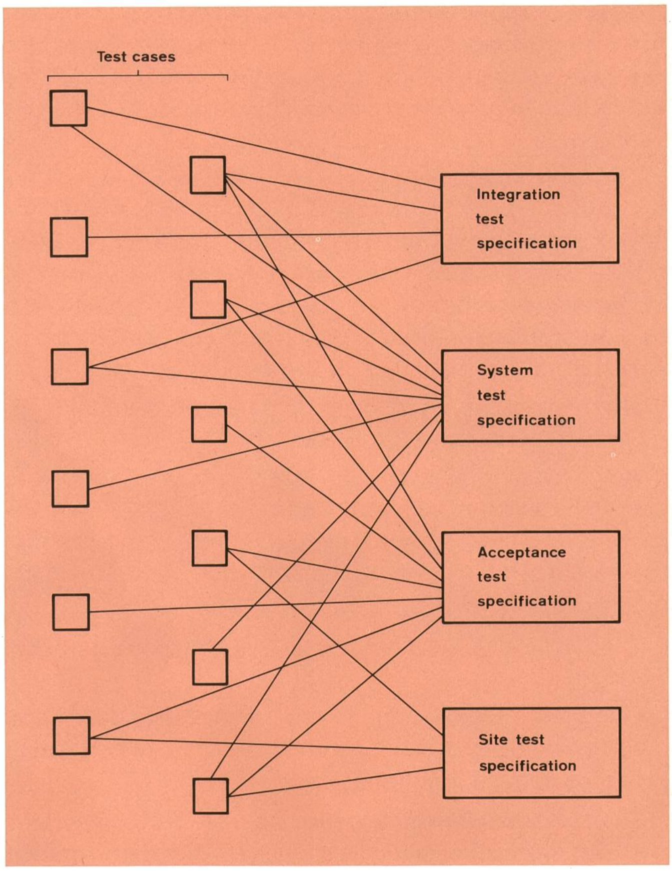

Fig. 7
The same test cases may be used for different test phases

However, the customer has to pay attention that the contractor does not misuse the user tests as an alternative to serious system test.

In addition, it is advisable not to start too early with the user tests. If the functions are yet too deficient and the system is too unstable, the effect on the users can be a lack of motivation. The users will have a prejudice and may not be confident in the future system.

9 Tools for Acceptance Tests of Communications and Teleprocessing Systems

Acceptance tests have to be accurate and reproducible. In addition, large scale systems need high test volumes. These two requirements are not easy to fulfill with terminals, that is the usual source and sink of traffic for teleprocessing and communications systems.

Terminals are manpower intensive. The accurate execution of a complex test script is difficult if input data has to be keyed in. The procurement of efficient test tools to rationalize the test operations may be of considerable help to the acceptance staff.

Some of the tools used for the ATECO and TERCO systems are briefly described, in order to give an idea of the requirements. As far as possible these requirements should be included in the initial specifications and in the contract.

91 Test Tools for the ATECO System [6, 7]

The input messages were systematically stored on paper tape. In fact, plastic tapes have been used, since they are more reliable and allow hundreds of readings without failures. All messages were entered via tape readers.

A part of the test messages was stored on a computer file. The messages were accessed randomly to prepare the necessary punched tapes. This facility eased the operations to prepare tapes for new tests or to duplicate used tapes.

The telex and gentex terminals need manipulations for the exchanges of identifications. The teletype machines have been equipped for the tests with additional electronics to detect the end-of-message trailers in a sequence of messages on a tape, and to stop the reader between two messages. This feature allowed one test person to serve up to five machines at the same time.

Demultiplexers were used to feed several point-to-point lines with one tape reader.

An extensive test cell with 150 telegraphic units was used (56 for input and 94 for output). By using demultiplexers, 215 circuits are activated. The test cell enabled the demonstration of the full peak traffic of system (6000 messages/h) *(Fig. 8)*.

The execution of the tests was relatively easy and very accurate.

Due to demultiplexers and end-of-message detectors, a full peak throughput test was possible with a small group of only 20 operators.

The test tools for the acceptance of ATECO were simple, but offered excellent services. The performance demonstration would not have been possible without them.

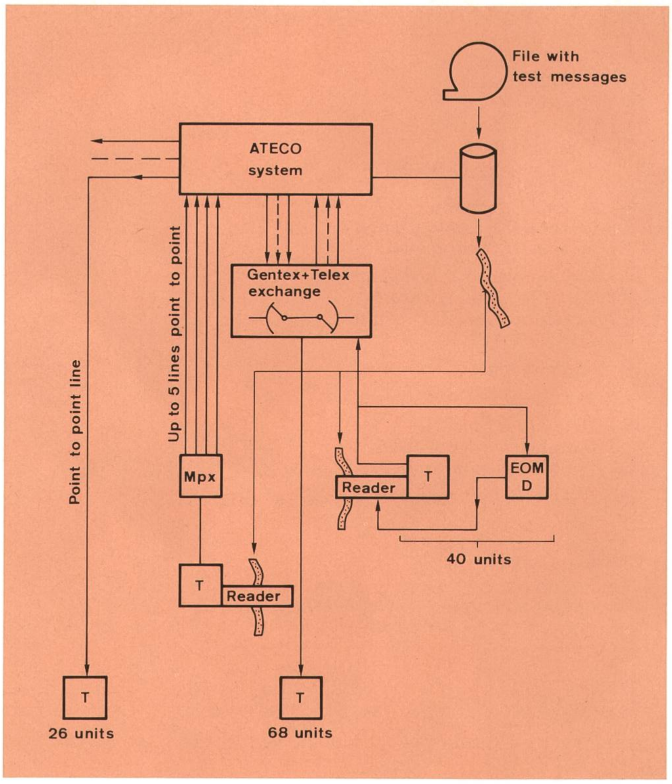

Fig. 8
Test tools for the ATECO system
Mpx Multiplexer
T Teletype unit
EOM D End-of-message detector

The problem of the test traffic generation was well resolved. On the other side no tools were available to assist the test staff in the analysis of the output messages. This point was the main weakness of the test methods, because every test (or repetition of test) required a tedious visual analysis of all output messages.

92 Test Tools for the TERCO System

The terminals of the TERCO system are visual display units. They are controlled by microprocessors but not easily programmable. It was not possible to automate the generation of test traffic in the VDU itself.

TERCO uses about 800 terminals. A test cell with 60 terminals was available. This number was limited for practical reasons (for instance, the available space in the computer centre) and essentially by the available test operators. Only a fraction of the peak traffic (10 %) could be generated with the test cell. Test tools were therefore necessary in order to, firstly execute accurate tests with minimal key-board manipulations during the functions demonstration and secondly generate enough traffic to carry out a meaningful performance demonstration.

The two requirements have been fulfilled partly with standard functions of the TERCO system and partly with auxiliary functions which have specially been developed for the acceptance demonstration.

921 Tools for the Functions Demonstration

One standard TERCO function — the 'Sequential Front-End' — and one special tool — the 'On-line Test

Case Monitor' — were available to automate the function tests.

The Sequential Front-End (SFE) is a software function, which allows to enter transactions in the system from tape units instead of terminals. The SFE is used in normal operation to process large batches of updates such as systematic changes of call numbers in the telephone directories. The function is also available for systematic routine testing of application programs. All on-line programs, in particular the data base functions, are activated in the normal way with exception of the data communications functions which are skipped *(Fig. 9)*.

The On-Line Test Case Monitor (OTCM) has been specially implemented for the functions demonstration. It allows a realistic demonstration of the TERCO functions at the terminals with minimal manual operations. The features of OTCM are the following:

- test cases (inputs and specified outputs) are stored on a disk-file, the test case reservoir
- a set of test cases can be selected for the execution of a particular test and stored on a test case disk file
- each selected test case input can be called from a terminal by a test case number
- the displayed input message is sent to the system for processing (in the same way as normal manual entered messages)
- the output message is displayed on the terminal
- input and output messages are logged on the system log tape
- the logged inputs and outputs are sorted and compared with the predicted output data stored in the test case reservoir
- input and output messages are printed in terminal format. Detected errors are automatically notified *(Fig. 10)*

30 test terminals can use the OTCM simultaneously. The OTCM can also be used to prepare input tapes and to check output tapes for the Sequential Front-End.

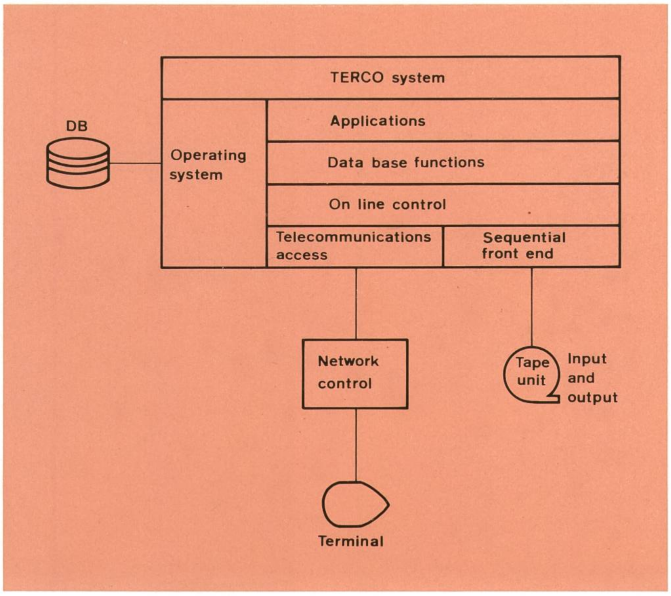

Fig. 9
A test tool for functions tests: The sequential front end
DB Data base

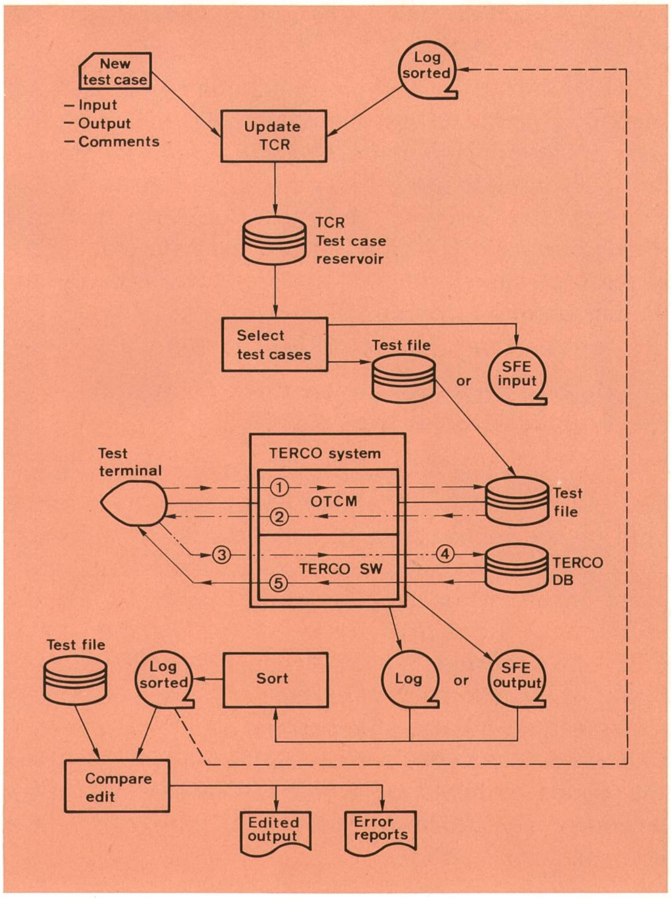

Fig. 10
TERCO on line test case monitor

TCR	Test case reservoir
SFE	Sequential front end
DB	Data base
OTCM	On line test case monitor
①	Call test case
②	Test-case input displayed
③	Transmit key
④	Test-case processed
⑤	Test-case output displayed
SW	Software

922 Tools for the Performance Demonstration

The traffic generator used for the performance demonstration was based on an extension of the Sequential Front-End. Additional functions have been implemented to feed the SFE from a tape unit with a definite message rate according to a definite statistical distribution *(Fig. 11)*. The message sequences stored on the input tapes were selected according to the message mix specified in the contract.

The traffic rate was adjustable within the range of specified figures.

The 60 terminals of the test cell were operated simultaneously with the SFE.

Throughput and system response time were measured by software for the total traffic. In addition, the effective response time was measured directly at the terminals of the test cell.

Special measuring equipment has been implemented to measure the response times automatically at the terminals of the test cell.

The available tools have allowed to demonstrate with a minimal manpower investment (only 60 terminal operators) that the specified throughput (22 messages/s) and response time (95 % <5 s) were achieved on the conditions stipulated in the contract.

The weak point of the method was the very low activation of the telecommunication front-end processors.

From this point of view the performance demonstration was not fully realistic.

During the system test phase the contractor used the secondary centre to test the communications performance of the primary centre *(Fig. 12)*. A network simulation package was installed in the secondary system to simulate the terminal clusters. However, this test method was not specified in the contract and in the acceptance specification. Therefore, it was not used for the performance demonstration.

10 Highlights of the Acceptance Tests and Suggestions for the Future

Acceptance test is a time and money consuming enterprise. Important manpower investments are needed both by the contractor and the customer to negotiate, plan, design, carry out and analyze the tests. Many man-years are usual for large projects. During the months spent on the acceptance phase, there is no return on investment. Every month of delay before system operation may cost many thousands of dollars. In all cases acceptance test has a rising effect on the initial project costs. One could ask whether such undertaking is justified. The experience gathered by Swiss PTT allows to answer positively. Nevertheless, one should be aware of the limits of acceptance test:

- No matter how exhaustively acceptance test is carried out, it will never guarantee with the present state of the art that the system is free of error. Problems may still be encountered in real operations *(Fig. 13)*.
- To carry out acceptance test under real life conditions is a very pretentious task. One can be very imaginative, but one cannot design tests to meet all surprises and unusual events that real operational environment presents.
- Performance requirements are often difficult to define accurately at the start of a project (at the time of signing the contract). If one gets 100 % performance according to the conditions specified in the contract, it does not yet guarantee that the system will achieve 100 % with real traffic. The requirements may have slightly changed or the initial estimations are incorrect.

On the other hand exhaustive and rigorous acceptance tests have many positive impacts on the whole project:

- The management of the customer receives a clear report on the achieved quality of service at the delivery time of the system. Measurable criteria are available

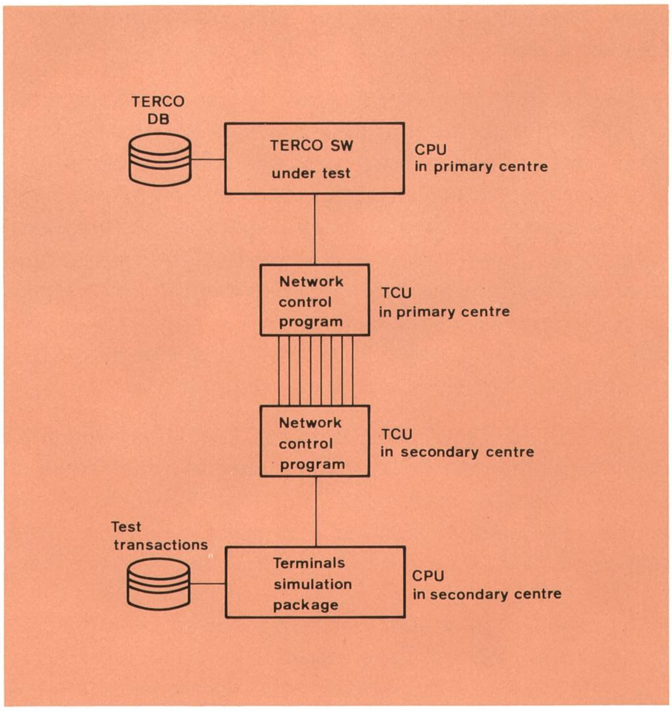

Fig. 12
Performance tests with a terminal simulation package

DB	Data base	CPU	Central processing unit
SW	Software	TCU	Telecommunication control unit

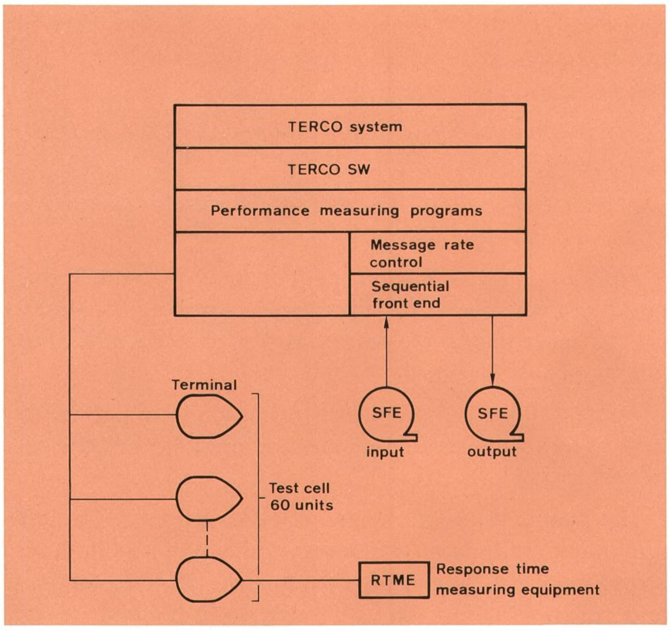

Fig. 11
Tools for TERCO performance tests

SW	Software	RTME	Response time measuring equipment
SFE	Sequential front end		

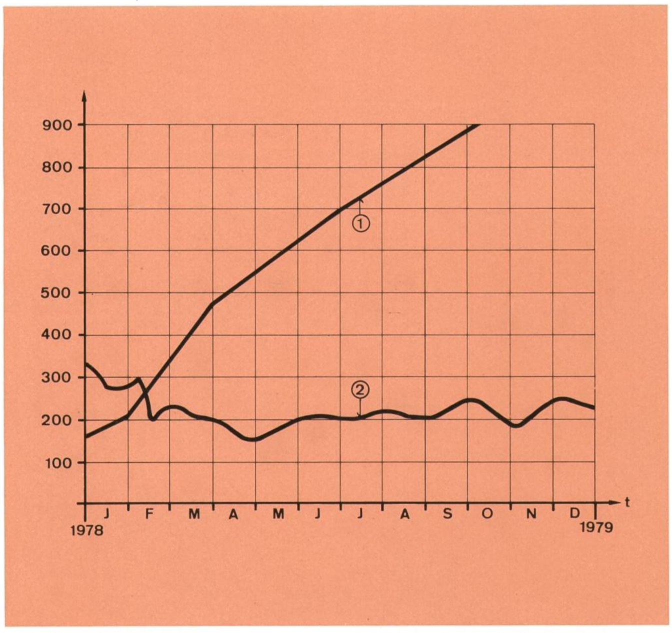

Fig. 13
One year of TERCO problems
① Number of registered problems
② Number of non resolved problems (average)

to decide if the system is ready for operation. The risk run by the organisation is minimized. This is especially important with systems dedicated to services which cannot tolerate long interruptions.

- The acceptance test phase constrains the contractor to have high quality standards for his own test activities. Acceptance tests may sometimes be considered as an uneconomical redundancy in regards to system tests. However, system tests alone may bring the temptation to shift part of the problems to the maintenance activities.
- Rigorous acceptance test has a positive effect on the stability of the system. It allows to begin the operation with confidence in the system reliability *(Fig. 14)*.

Some suggestions may be given for organisations faced in future with the acceptance of large systems:

- Consider acceptance problems as early as possible in the project cycle.
- Let all levels of management be concerned that acceptance activities are an important and necessary part of the project.
- Be thorough at negotiating the acceptance specifications as tests that are not required at the beginning may be difficult to include as soon as problems and delay occur.
- Negotiate the final contents of the tests as late as possible in order to use the growing understanding of the implemented system.
- Select the right people for the customer's acceptance group. They must be competent and thoroughly understand the job at hand. They have to be insistent with the contractor, but with enough understanding to keep the proper contact with him.
- Involve the users in the acceptance tests. The real acceptance is finally the matter of the users. They have to live with the system.
- Give the main weight of the acceptance tests on the parts of the system, which will be difficult to maintain and to improve by the user's organisation (special system software, reliability mechanisms, performance tuning). Concentrate on the stable functions as these efforts will be more rewarding than on functions which are quickly subject to change. One of the objectives of the acceptance tests is to reduce the investments for maintenance after setting the system in operation.

11 Points for Further Improvements

Test tools and methods have not reached the final state of the art. Many points have yet to be improved. Some of them are given as a conclusion and a challenge to the computing community:

- Usual testing methods allow to find errors, but not to prove that all errors are cleared off. Verification and certification methods are yet needed. Automated testing is to be aimed at.

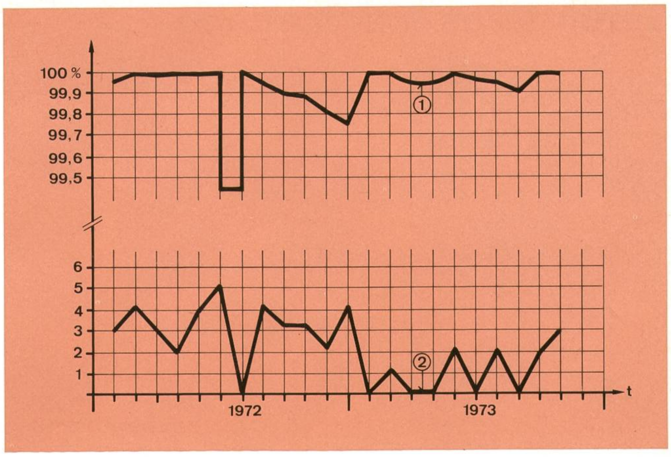

Fig. 14
Reliability of ATECO after cutover
① Availability (with operator stops included)
② Number of total break-downs/month

- A contractor should be able to quantitatively indicate to his customer the degree of testing which has been reached (e.g. 95 %) for system. Such a figure should be measurable ([3] gives some directions for this requirement).
- Better tools are needed for functions and performance tests. Tools such as traffic generators, or terminals and data communication simulators, should be part of the standard software. Dedicated specialized systems like traffic simulators should be available. Future intelligent terminals should integrate functions for automated testing of hosts systems.
- The maintainability of the software should also be testable. Methods should be available to measure it, because maintenance is the huge problem of computer systems all over the world.

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