Recovery through programming system/360—system/370

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INTRODUCTION

Recovery Management can be defined as the operational control of those system facilities (both program and machine) which strive to effectively deal with detected machine malfunctions within an operating system. Its primary concern is to maintain total system operation with minimum impact upon the availability of system resources.

Recovery Management, defined above and treated in this report, refers to recovery from an unscheduled system interruption resulting from a machine malfunction. As such, Recovery Management can be viewed as a consideration which leads to a higher degree of total system reliability, serviceability, and availability.

Effective Recovery Management is not a luxury; on the contrary, it may, in a given system, be a necessity. Without it, what need only be a minor problem becomes a major problem, possibly a catastrophe.

Recovery Management facilities service unscheduled system interruptions originating within an I/O device/unit, channel, processor storage unit, or central processing unit. The presence of such an interruption is indicated by a device/unit, channel, or machine-check condition. No individual Recovery Management facility services all machine malfunctions.

Recovery Management facilities attempt recovery at different levels; these levels differ with respect to the consequences imposed upon the system during the recovery process. Not all of the Recovery Management facilities have the capability of effecting recovery at each level. Some Recovery Management facilities are optional, and as such, must be specified by the user at system generation time. Considering that Recovery Management facilities are directed at specific types of failures, only after the thorough analysis of an installation’s applications and requirements should a Recovery Management package be structured.

THE RECOVERY MANAGEMENT OBJECTIVE

The objective of Recovery Management is to provide the user with a higher degree of system availability (more time for more jobs) by minimizing the impact of machine malfunctions upon the user’s operations. This objective is realized with the successful achievement of the following goals:

- Reduce the number of unscheduled system interruptions resulting from machine malfunctions.
- Minimize the impact of such interruptions in the event they do occur.

Through Programming, interruptions to the user can be reduced, their impact minimized and their causes isolated. There are a number of functions which can be performed to achieve these objectives of Recovery Management. Some of these are:

- Instruction Retry—The concept of instruction retry is not new. It is something IBM has been doing for years, particularly in the I/O area. Instruction retry has been standard procedure whenever an error was encountered in reading or writing a tape. It is possible to extend this retry capability and to employ it when a CPU or main storage malfunction occurs. A relatively large number of malfunctions are intermittent in nature, rather than being solid failures; therefore, there is a high probability of success of execution and recovery if an instruction retry can be attempted.
- Refreshing Main Storage—If instruction retry cannot be accomplished, one function which could be of value would be the ability to refresh main storage. Through this damage which either caused or was caused by a malfunction could be repaired.
This function could be accomplished by loading a new copy of the affected module or "Csect" into main storage or by a process known as check summing.

- **Selective Termination**—This function would enable the system to examine the failing environment, determine what problem program was executing and then proceed to terminate this program while entering all other jobs which were executing at the time of the malfunction. This is really a type of job which "frees" the resources of the system allocated to the job and makes them available for future use. This process results in the loss of a specific job but it keeps the system alive.

- **I/O Recovery**—The above functions have been directed mainly to errors which occur in the CPU or main storage. From an examination of system incidents, it is evident that a certain portion of errors occur in the I/O area. Recovery could be accomplished by I/O retry which is available through the error recovery procedures for the different I/O devices. Another group of I/O errors—channel control checks, channel data checks, and interface control checks—may be analyzed and under certain conditions a retry can be attempted. The I/O device or medium can malfunction and if retry is not successful the ability to switch data sets may be provided and then retry the operation on the new drive. Another is to try alternate routes to the same device, that is by addressing a device through a different channel or control unit.

- **Operator Awareness**—A group of system incidents is due to procedural and operator errors. Several things can be done to decrease these errors such as better trained personnel, minimal control information and clear and concise operator messages.

All of these functions are aimed at continuing the operation of the system. This is not always possible to accomplish. Therefore, the next best thing is to minimize the effect of the malfunction. This can be done by attempting to preserve information concerning the malfunction and to make it available to assist personnel to determine what caused the error and what can be done to correct it. Recording, therefore, is a major part of recovery management.

Recovery Management support has provided a number of these functions in the operating systems. RMS has provided a hierarchy of recovery which involves four levels of error recovery.

I Functional Recovery—Retry the interrupted operation

II System Recovery—Terminate the affected task

III System-Supported Restart—Prepare for Re-IPL

IV System Repair—Require stop for repair

**Functional Recovery**

Functional recovery is achieved when an interrupted operation is successfully retried. Such recovery is extremely desirable from a system point of view, because it makes the entire incident transparent to the user.

**System Recovery**

System recovery is achieved when system operation is maintained although an interrupted operation has not been successfully retried. This effort involves: an analysis of the failure's environment, a repair of the damage associated with the malfunction to prevent further interruptions, and/or an attempt to associate the malfunction with a particular task in order to allow selective termination of the affected job and continued processing of the unaffected jobs.

**System-Supported Restart**

System-supported restart is achieved when a stop for repair is not required and system operation is re-started using an Initial Program Load (IPL) procedure supported by System Restart facilities. (System Restart facilities aid the IPL procedure by preserving and using system job and data queues.)

**System Repair**

System repair, the lowest but most critical level of error recovery, consists of stopping the system and repairing a malfunction which cannot be serviced by the particular recovery facility at any of the previous levels. Recovery Management facilities aid maintenance personnel by providing them with detailed error analysis records. There is always, however, the possibility that system damage will be severe enough to preclude retrieval of the error records. In those cases, personnel will have to make use of the System/360 diagnostics available to them.

The levels of error recovery applicable to IBM Operating Systems operations are illustrated in Figure 1; the outcome of recovery procedures I, II, or III determines the level at which recovery will be effected. The bracketed information on a given flowline indicates the consequences of recovery at that level.
USER PERSONNEL INVOLVEMENT

The successful operation of a Recovery Management package is directly proportional to the planning for and use of specific facilities in a given operating system.

Once a user has determined what his needs and requirements are, the amount of specification required to tailor his Recovery Management package is minimal. The selection of some recovery facilities is made during the system generation process. Modifications can be made during the IPL/NIP process.

The programmer's responsibility varies greatly with respect to the Recovery Management options available to him:

- He may code actual error recovery routines which will receive control through macros specifying user exits (see Optional User Written Routines).
- He need not involve himself at all with regard to certain Recovery Management facilities.

Once the system has been set up and is running, it is the operator's responsibility to be aware of and responsive to the parameters required by, and the messages and wait state codes issued by particular Recovery Management facilities.

Maintenance personnel should acquaint themselves with the scope and operation of those Recovery Management facilities incorporated into the systems for which they have responsibility. They must be familiar with the messages and wait-state codes issued, and the error records produced, if they are to make effective use of the information available to them.

SUMMARY DESCRIPTION OF FACILITIES

This section briefly describes the available Recovery Management facilities. Included are discussions of the Machine-Check Handler (MCH), the Channel Check-Handler (CCH), and I/O Recovery Management Support (I/O RMS). The individual recovery facilities are discussed as they apply to specific types of failures, or to specific recovery functions. The topics of discussion are:

- I/O Device/Unit Recovery Facilities
- Channel Recovery Facilities
- I/O Recovery Management Facilities
- CPU/Processor Storage Recovery Facilities
- System Associated Recovery Facilities
- Error Record Retrieval Facilities

The following points are made to clarify the function and scope of those recovery facilities which cross the bounds of two or more failure types:

- The Optional User Routines receive control from the IBM supplied Error Recovery Procedures (ERPS) on permanent I/O device/unit errors in order to determine whether their associated tasks are to be terminated.
- The System Environment Recording Routines (SERO, SER1 and the Machine-Check Handler (MCH) program can perform recording functions for channel and machine-check conditions. However, the limited SER1 and extensive MCH recovery capabilities deal only with machine-check conditions. Therefore, if one desires channel recovery, he must also make use of the Channel-Check Handler (CCH). CCH may be used in conjunction with MCH, SER0, or SER1.
- The System Environment Recording Editing and Printing (SEREP) program may be used to record, edit, and print I/O device/unit, channel, CPU, and processor storage conditions. SEREP will be used when no automatic recording facility has been invoked, the facility invoked has failed in its operation, or the recorded records cannot be retrieved by the Environment Record Editing and Printing (EREP) program. EREP is a utility which edits and prints those error analysis records placed on the SYS1.LOGREC data set. This data set resides on the system residence device and is reserved for the exclusive use of all those recovery facilities which generate error analysis records.
I/O DEVICE/UNIT RECOVERY FACILITIES

The problem of malfunctions occurring within I/O device/units has been a concern for quite some time. The facilities available for the servicing and detection of these failures are:

- IBM Standard Error Recovery Procedures
- Optional User Written Routines
- On-Line Test System

IBM standard error recovery procedures

Standard error recovery procedures (ERPs) exist for I/O devices/units in order to maintain device performance and to provide uniform recovery procedures for all failures. The three types of IBM-supplied error routines are:

- Device-dependent routines
- Common routines
- I/O Recording routines

The device-dependent routines attempt functional recovery for particular device types by retrying operations a specific number of times. If functional recovery is not possible, control is passed to an optional user-written routine for further determination. Device-dependent routines exist for:

- Teleprocessing Devices
- Unit Record Devices
- Tape Devices
- Direct Access Devices
- Graphic Devices

The common routines are used by the device-dependent routines to analyze the type of error, to issue console messages, and to update the statistics table.

The I/O recording routines are the outboard recorder (OBR) and the statistical data recorder/channel-check recorder (SDR/CCR). OBR produces records for permanent I/O device failures on the SYSIL.OGREC data set. SDR/CCR updates the statistic counters on the SYSIL.OGREC data set whenever one of the error statistics counters in the statistics table overflows, and places I/O inboard records produced by the optional Channel-Check Handler (CCH) on the SYSIL.OGREC data set. The records placed on the SYSIL.OGREC aid maintenance personnel at the System Repair level.

Optional user-written routines

Should an installation determine that available Recovery Management facilities do not fill a need unique to the installation's requirements, user-written routines may be added to the system. When in the system, user-written routines are given control through the DCB macro instruction (SYNAD and EROPT). The user routine can determine on certain I/O device conditions if its associated task should be terminated.

On-line test system

The purpose of the On-Line Test System is to test the functioning of I/O devices in a controlled environment with minimum interference to the operating system. The On-Line Test System consists of an executive program, a series of tests for I/O devices/units, and a special SVC to perform functions required in the OS nucleus. The executive program serves as an interface between the operating system and the unit tests. It schedules and controls the running of the tests and provides communication with the operator. The use of the On-Line Test System serves to insure the integrity of the system's I/O devices. It might be considered preventive Recovery Management since its use should lead to the repair of faulty equipment prior to failure during system operation.

CHANNEL-CHECK HANDLER (CCH)

The Channel-Check Handler is designed to increase machine availability by minimizing the effects of channel malfunctions for 2860/2870/2880 and System/370 Model 155 channels. Without CCH, such malfunctions would be system incidents. The Channel-Check Handler will (1) determine the effect on the system of particular conditions that may have occurred, (2) set error indicators in the Error Recovery Procedure Interface Bytes (ERPIB) for the Error Recovery Procedure (ERP), and (3) create a record of the channel-error condition.

Unlike MCH, which is model dependent, CCH is only channel dependent because the Channel I/O Log-out area is the analysis material used by the CCH program.

CCH includes the Dynamic Loading feature, which enables the main part of CCH (channel and model independent) to link to the various channel-dependent analysis routines. (See Figure 2.) Dynamic Loading also allows dynamic configuration for the specific channels on-line at NIP time, even if more channels were specified at SYSGEN time.
The Channel-Check Handler receives control from the I/O Supervisor (I/O S) after detection of a channel control check, channel data check or an interface control check. CCH then completes its analysis to the error condition by setting up the ERPIB for the ERP or by indicating that immediate retry or termination is necessary. If termination is indicated, the error is recorded on the SYS1.LOGREC data set and a wait-state condition is set. If immediate retry is indicated, control is then returned to IOS who performs the retry and passes control to the next processing program on a successful retry. This retry is for special I/O operations such as SENSE. If an ERPIB has been created, IOS schedules the appropriate device ERP which operates in the Error Transient Area and receives a pointer to the ERPIB. (See Figure 3.) Based on the ERPIB information, the device ERP can determine whether a retry of the failing operation can be attempted or if the operation must be considered a permanent error.

For permanent error conditions, a message to the operator is printed (WTO Error MSG), the statistical data counters (STAT Update) for the devices are updated, a record of the permanent error condition is made on the SYS1.LOGREC data set by the Outboard Recording Routine (OBR), and an exit is taken. For errors marked as retryable, a retry is attempted and, if successful, control is passed to STAT Update to update the statistical data counters and then to OBR, which records the successful Channel-check recovery.

Functional Recovery is achieved on channel errors that can be successfully retried by CCH or the device ERP. CCH enhances the performance of OS/360 by reducing the number of system incidents resulting from channel malfunctions.

I/O RECOVERY MANAGEMENT SUPPORT

I/O Recovery Management Support (I/O RMS) is an extension to existing functions of the Operating System that address the availability and reliability needs of IBM customers that may not be realized due to channel, control unit, device, and medium failures.

Initially, these functions encompassed only the Device Dependent Error Recovery Procedures (ERP's), which were designed to effect a retry of a device failure on a particular path after a unit-check condition. Subsequently, with the implementation of the Channel-Check Handler (CCH), the utility of the ERP's was extended to effect a retry of channel failures (channel checks). In order to meet the continuing need for higher availability and reliability, I/O RMS provides two additional optional system functions that may be used to address the problem of I/O errors: Alternate Path Retry (APR) on the channel level and Dynamic Device Reconfiguration (DDR). (See Figure 4).

Without these functions, when an ERP is unable to successfully retry an I/O operation, permanent error is indicated. When a program encounters a permanent I/O error, it either accepts the error and continues, or ABENDS. If a critical supervisor function encounters a permanent I/O error, the system terminates.

APR

I/O RMS extends recovery from an I/O error with APR by ensuring that a different channel will be tried.
DDR

DDR extends I/O recovery when a permanent error develops on a device with a demountable volume by causing the system to request that the volume be moved.

The operator may also request DDR during normal execution to allow a volume to be moved from one device to another. A DDR can be operator-requested for volume cleaning, etc.

DDR can also be requested by the operator during "intervention required" conditions on readers, printers, and punches.

DDR will support the 2400 tape series, the 2420-7 tape, the 2311 and 2314 disks, the 2321 data cell drive, and readers, punches, and printers.

DDR can be requested by the operator anytime during execution, or by the system after a permanent error for all 2400 (including 2420-7), 2311, 2314, and 2321 devices. DDR can be requested only by the operator for readers, printers, and punches during "intervention required" conditions. "Intervention required" is either indicated by the system or may be caused by the operator. (The operator may cause an "intervention required" condition by making the unit "not ready.")

DDR's support of the 2314 allows the operator to move a volume to a drive on another 2314. It also allows the operator to move all data cells from the failing 2321 to another 2321. DDR will not allow the swapping of data cells on one device.

If the SYSRES option is selected, the SYSRES volume may be moved from one device to another at the request of the system or of the operator. The system will not request SYSRES swap unless a critical I/O operation is involved. (A critical I/O operation is one which involves the SVC library.)

If high availability is important to the installations, a duplicate SYSRES volume would be advisable. In order to use such a volume, writing on SYSRES would have to be prohibited except for the SYSLOGREC data set. Therefore, no libraries on SYSRES could be updated, no work data sets could be allocated on the SYSRES device, and SYSL.SYJSJOBQE would have to be on a volume other than SYSRES. If the installation had such a duplicate volume, as well as an additional available SYSRES device, it would be possible to recover from both a device error and a media error.

SYSRES Option: Since some users do not have a demountable SYSRES device, DDR support SYSRES will be an option at SYSGEN time. Thus, the resident code necessary for SYSRES DDR is included only when the option is taken.

Dynamic Device Reconfiguration is an extension of IOS as it applies as much to device errors as channel errors.

With I/O RMS, a device encountering an error channel prone path may be able to continue operating on a different channel path. A volume on an error-prone device may be used effectively on a different device. Specifically, bus-out checks, and data checks, along with other error types, will have a higher degree of recovery, since a path to the volume may be made available that excludes the source of error.

I/O RMS is not model dependent.

In summary, I/O RMS will extend device performance in areas that may have previously rendered a job or the system inoperative.
CPU/PROCESSOR STORAGE RECOVERY FACILITIES

Machine-check conditions which arise within the CPU or processor storage are serviced by the mutually exclusive recovery facilities MCH, SERO, and SER1. If none of these are chosen at SYSGEN time, the default condition is a wait state. That is, when a machine check is encountered, the machine goes into a wait state. If such a wait state condition occurs or should a facility fail in its recovery attempt, SEREP may be used to access the CPU logout. (MCH is mandatory in the System/360 Model 85 and System/370 Models 155 and 165.)

MACHINE-CHECK HANDLER (MCH)

The primary function of the Machine-Check Handler is to attempt recovery from main storage or CPU failures which ECC or HIR has not previously corrected. An important additional function is to record each failure. The goal of MCH is total recovery, achieved when the interrupted program is enabled to continue processing at the point where the interruption occurred. When total recovery is not possible, MCH attempts to terminate the affected task without halting the entire system. If, however, a stop in system processing cannot be avoided, the error records produced by MCH aid manual repair.

MCH processing is inseparable from the operations of the machine recovery facilities, ECC and HIR. Upon detection of a hardware failure, either ECC or HIR (depending on the type of error) receives control. Only after these circuits make their recovery attempt does a machine-check interruption occur. MCH receives control at the interruption by means of the machine-check new PSW which contains the address of the MCH Resident Nucleus. Figure 5 illustrates the sequence of operations performed by MCH.

The path followed by MCH processing depends on whether or not the machine facilities were successful in their recovery attempt. If so, MCH only records the error, after which control is returned to the system. If the recovery attempt was unsuccessful, MCH analyzes the error and attempts recovery. If recovery is achieved, MCH records the error, notifies the operator, and returns control to the system. However, should recovery not be effected, MCH attempts to record the error, informs the operator of the condition of the system, then enters the disabled-wait state.

NOTE: In System/360 Model 65, Instruction retry and single bit error correction are performed by the program.

System environment recording (SER0 and SER1)

These optional recovery facilities record machine malfunctions of the CPU, processor storage, and channels in System/360 Models 40, 50, 65, 75, and 91 (SER1 only). After an error record has been placed on the SYSLOGREC, the system is placed in the wait state. If system repair is not required, a message is issued to the operator requesting him to re-IPL (System-Supported Restart). In addition to the recording function, SER1 attempts to associate the failure with a specific task. If the failure affects only the job step associated with the current task, the job step can be terminated without requiring a complete stop of the system (System Recovery).

Figure 5—MCH gross flow

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SYSTEM ASSOCIATED RECOVERY FACILITIES

While the following facilities do not actually record or analyze errors, they are an integral part of the Recovery Management scheme in that they further reduce the time involved in recovering from a malfunction which has caused an interruption in system operation:

- System Restart
- Checkpoint/Restart

System restart

The system restart facilities aid the IPL procedures by allowing the system to resume operation without having to reenter jobs that have been enqueued. This is especially time-saving in the case of those malfunctions which require a halt of system operation without a stop for repair. Information concerning input work queues, output work queues, and jobs in interpretation, execution, or termination is preserved for use when the system is reloaded. When the system is restarted, a message is written to the operator describing the status of each job in the system.

Checkpoint/restart

The checkpoint/restart facility provides the capability of restarting program processing subsequent to an I/O device/unit error, machine check, channel check, intentional operator intervention, or similar event. Job step information is recorded at user designated checkpoints in a problem program; if restart becomes necessary, it can be initiated from an available checkpoint.Checkpoint/restart can be invoked subsequent to system restart or subsequent to the abnormal termination of an effected job by one of the recovery facilities.

Use of this facility minimizes time lost in reprocessing a job step that has been terminated. It is used to best advantage in programs of long duration, or with programs where restarting from the beginning would be difficult.

ERROR RECORD RETRIEVAL FACILITIES

Although automatic recovery procedures are extremely desirable, such recovery is sometimes impossible, and human intervention on the part of maintenance personnel is required. The following facilities are part of the Recovery Management scheme, in that they facilitate system repair by providing a means of accessing failure data:

- Environment Record Editing and Printing (EREP) utility
- System Environment Recording Editing and Printing (SEREP) program

Environment record editing and printing utility

EREP, running under the operating system, edits and prints error records generated by OBR, SDR/CCR, CCH, SER0, SER1, and MCH and recorded on the SYSLLOGREC data set.

The EREP utility program can edit and print:

- Combinations of the above records
- Records that were generated within a specific period of calendar time
- I/O outboard or statistical count records, or both, related to a specific channel or unit
- I/O outboard or statistical count records, or both, related to a specific I/O device type

EREP normally clears each selected record to zeros in the SYSLLOGREC data set when processing of that record is complete. However, an option can be specified to prevent the clearing of selected records. Thus, a log of specific error conditions can be retained in the data set.

EREP output provides information for interpretation by the people performing the repair function.

A standard operating procedure in a Computer Center using MCH and/or CCH should be to execute EREP on a regular basis and then the information would be available to repair personnel as an aid or indicator to anticipate serious trouble. Upon review, if a particular pattern appears—indicating possible degradation, preventative maintenance may be performed before the occurrence of a serious incident.

System environment recording, editing and printing program

SEREP, is used to access failure information when:

- No automatic error recording facility (SER0, SER1, CCH, MCH, OBR, SDR/CCR) has been invoked
- An automatic error recording facility has failed in the performance of its function
- The SYSLLOGREC data set cannot be accessed to obtain the error analysis records
SEREP is manually loaded using the standard IPL procedure. The program prints the information regarding the failure's environment on an online printing device. The SEREP procedure is aimed at improving the overall performance by minimizing unscheduled downtime. The program allows maintenance personnel to take full advantage of the machine diagnostic capabilities of the system in analyzing and correcting the following types of machine malfunctions:

- I/O Channel Failure
- I/O Device Failure
- I/O Test Channel Failure
- I/O Device Not Operational
- Machine Check Failure

RMS/65 RELATIONSHIP TO THE OPERATING SYSTEM

The RMS/65 package is comprised of two components, the Machine Check Handler (MCH) and the Channel Check Handler (CCH). For System/360 Model 65, both components are optional and a user at SYSGEN time may choose (1) CCH only, (2) MCH only, or (3) both MCH and CCH, depending on the needs of the installation. For System/360 Model 65 and System/370 Models 155 and 165, the MCH and CCH are an integral part of the Control System and, therefore, are not an option.

When selected at SYSGEN time, the components of RMS are included as part of the resident OS Nucleus. See Figure 6.

SYSTEM/370 CONSIDERATIONS

The current program status word (PSW) bit 13 has taken on more significance in System/370. In System/
360, bit 13 had sole control of Recovery Management functions. In System/370 there are recovery submasks in the control registers area which function in conjunction with bit 13 of the current PSW. Therefore, if bit 13 of the PSW is one submask and the subclass mask bit in the control register is another, the associated condition will initiate a machine-check interruption. If either bit is zero, an interruption would not be initiated. Some subclass condition masks are system damage, timer damage, system recovery, etc.

Permanently allocated storage locations have been extended in System/370 for machine-check handling. Storage locations 168 thru 512 contain the added information for handling machine checks. (See Figure 7.) This information is supplied to assist in performing the recovery function. Such information consists of Channel ID, I/O extended by log-out pointer, limited channel log-out, I/O address, machine-check interruption code (discussed below), failing storage address, floating point, general and control registers as well as model dependent areas.

The Machine-Check Interruption Code is a double word starting at location 232. It contains such information as the time of interruption occurrence, machine-check intended log-out length, and subclasses. A subclass identifies the machine-check condition which caused the interruption. Some subclass conditions that can be indicated are system damage, instruction processing damage, timer damage, external damage, automatic configuration (when performed by hardware) and storage error type (whether corrected or uncorrected).

CONCLUSION

I believe that effective error recovery is a partnership between engineering and programming and these two must form a partnership and attack the problem together in order to provide a satisfactory solution. Recovery Management Support is a step in the direction which Error Recovery must take if the requirements of computer technology are to be met in this area. Every sign indicates that this is being accomplished.

It appears that some meaningful steps are being taken toward the goal of reducing the number of interruptions to which a user is exposed and to minimizing the impact of these interruptions when they do occur.

REFERENCE MATERIALS

IBM System/360 Operating System—System Reference Library

- Concepts and facilities: GC28-6535
- Operator's reference: GC28-6591
- MFT guide: GC27-6939
- MVT guide: GC28-6720

IBM System/360 Operating System—Program Logic Manuals

- I/O supervisor: GY28-6616
- MVT job management: GY28-6660
- MCH for model 65: GY27-7155
- MCH for model 85: GY27-7184

IBM System 360 Operating System

Machine check handler for the IBM System/370
Models 165 and 165, systems logic: GY27-7198

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