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IBM System/360 Models 25, 30, 40, 44, 50, 65, and

IBM System/360 Model 20-Special Feature Description

# Optical Mark Reading for IBM 2501 Card Reader and IBM 2560 Multi-Function Card Machine

This publication describes the Optical Mark Reading special feature available on RPQ basis for the IBM 2501 Card Reader, Models A1, A2, B1 and B2 and the IBM 2560 Multi-Function Card Machine, Models A1 and A2. Descriptions of the operating principles, programming considerations, and mark read card layout are included.

The reader is assumed to be familiar with the standard functioning of these machines as described in Systems Reference Library manuals *IBM 2501 Card Reader, Models A1 and A2 Component Description and Operating Procedures,* Form A26-5892, *IBM 2501 Card Reader, Models B1 and B2 Component Description and Operating Procedures,* Form A21-9026, and *IBM 2560 Multi-Function Card Machine, Models A1 and A2 Component Description and Operating Procedures,* Form A26-5893.

*First Edition* (November, 1969)

Changes are periodically made to the specifications herein; before using this publication in connection with the operation of IBM equipment, refer to the latest *SRL Newsletter, Accumulative Index of Publications and Programs – IBM 1130* (Form N20-1130), *Accumulative Index of Publications and Programs – IBM System/360* (Form N20-0360), or *Accumulative Index of Publications and Programs – IBM System/360 Mod 20* (Form N20-0361) for the editions that are applicable and current.

Text for this manual has been prepared with the IBM 72 Composer.

Requests for copies of IBM publications should be made to your IBM representative or to the IBM branch office serving your locality.

Address comments concerning the contents of this publication to IBM Laboratories, Special Engineering, Dept 763, 703 Boeblingen/Wuertt, PO Box 210, Germany.

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Note: The illustrations in this manual have a code number to the right of the caption. This is a publishing control number and is unrelated to the subject matter.

## Abbreviations

| | |
|---|---|
| I/O | Input/Output |
| OMR | Optical Mark Reading |
| RPG | Report Program Generator |
| RPQ | Request for Price Quotation |
| UMC | Undefined Mark Check |

Optical mark reading increases the flexibility of data input and offers high speed processing of manually collected data. It is used for applications connected with public utilities, meter reading, inventory control, manufacturing control, ordering procedures, public census, banking, votes, credit cards, and distribution. A great number of applications presently performed on other equipment may be simplified and accelerated. Because the feature processes data directly and has a high speed and reliability, it is especially suited for both new and previously unattractive applications. It is suitable for all kinds of data collection on cards.

The Optical Mark Reading (OMR) special feature available on RPQ basis provides new input capabilities for the IBM 2501 Card Reader and the IBM 2560 Multi-Function Card Machine. The OMR feature enables the 2501 Card Reader and the 2560 Multi-Function Card Machine to read hand-made marks as well as punched holes from standard 80-column punch cards directly into the storage of the processor. Standard punch cards and OMR cards may be intermixed and read in any sequence. The OMR cards may contain both holes and marks, but in OMR fields (see definitions) punch holes are not allowed. The fields are read in one pass.

The marks are recognized by photo-sensitive cells which detect differences in reflectance. Therefore, the marks do not have to meet any electrical or magnetic specifications and are treated like punched holes, the same codes and code translation being used.

## APPLICABLE MACHINES

The optical mark reading special feature can be installed on the following machines:

1. *IBM 2501 Card Reader, Models A1 and A2* (Figure 1), connected to either the IBM System/360 Model 20, Submodel 2 or 5, or the IBM 1130 Computing System via integrated attachments.

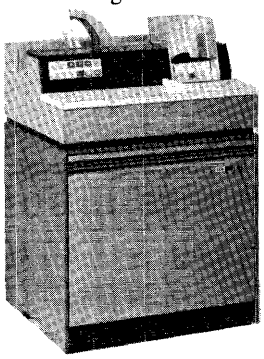


Figure 1. IBM 2501 Card Reader [01745]

2. *IBM 2501 Card Reader Models B1 and B2* connected to System/360 Model 25, 30, 40, 44, 50, or 65 via the standard interface.

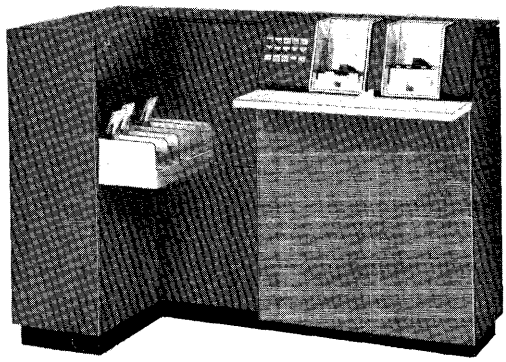


Figure 2. IBM 2560 Multi-Function Card Machine [01747]

3. *IBM 2560 Multi-Function Card Machine, Model A1,* (Figure 2), connected to System/360 Model 20 Submodel 2 or 5 via integrated attachments.

4. *IBM 2560 Multi-Function Card Machine, Model A2,* connected to System/360 Model 20 Submodel 3 or 4 via integrated attachments.

No prerequisites or companion features are necessary in the processor or in other machines within the system, (except for 2501 Models A1 and A2 and 2560 connected to the System/360 Model 20 for use of Report Program Generator (RPG) and Utility Programs). The feature is plant and field installable.

Approval to order must be obtained via RPQ (Request for Price Quotation) from the Special Equipment Engineering Department in the country concerned in all circumstances.

## ADVANTAGES

In addition to its normal functions, a machine with this feature is able to read hand-made marks representing data directly into the storage of the CPU. Off-line punching of marked data is not therefore necessary. The marks are encoded in a similar manner to punched holes, so that data from marks and holes appear identical in the storage. All valid punch codes can be marked.

OMR cards and standard punched cards can be read intermixed. No special OP-Code is necessary for mark reading since the recognition of OMR cards and mark fields is done automatically by means of preprinted identification and control marks. Marks and holes on an OMR card are in separate areas. Both are read in the same machine cycle and by the same read station.

The normal functions of the machines are not affected by OMR. The high speed of the 2501 and all multiple functions of the 2560 are still available and can be used also with OMR cards.

## DESIGN PHILOSOPHY

The OMR feature can recognize and read black marks in particular areas on the card. When these areas are illuminated, the marks reflect less light than the card stock. This difference is picked up by photo-cells when the card passes the read station. Signals representing the pattern of activated photo-cells are amplified, sent to the translating circuits and stored in the data register which is also used for punched data.

The illumination for the areas mentioned in the preceding paragraph is provided by a lamp shining through a glass fiber bundle. The glass fiber bundle distributes the light to 13 positions in the lower read head (Figure 3). Thirteen photocells are arranged to pick up the reflected light from 12 data rows and one control mark row on the card. For hole reading the distributed light passes through the holes in the card and is picked up by 12 phototransistors in the upper read head. The 13th position is not used in hole reading.

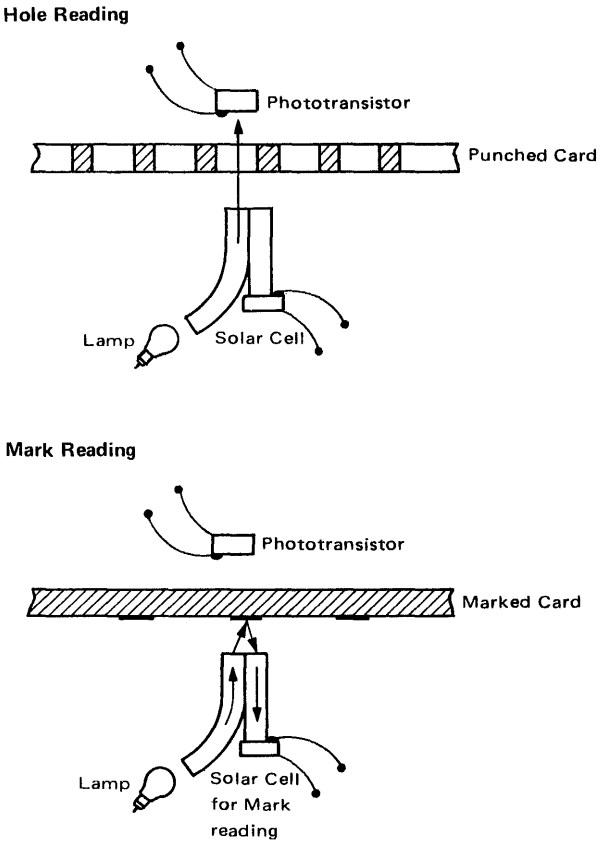



Figure 3. Hole Reading and Mark Reading [06503]

With the feature installed, the card path and the transport devices of the machines are not changed. The identification marks in front of column 1 (Figure 4) are provided for the recognition of OMR cards. The control marks located below the 9 punch row signal the beginning and the end of the mark fields.

No information is provided to the processor to indicate whether marks or holes are being read. The card type should be checked by program by using a card type code.

## OPERATING PRINCIPLES

The maximum number of mark columns possible is 40 per card as one mark column requires the same space as two punch columns. The mark columns are located in the middle of two successive punch column positions, either between an odd and an even or between an even and an odd position. For detailed card layout information see "OMR Cards".

The standard machine controls and operating procedures are not changed when this feature is installed (see description of particular standard machine).

## CHECKING

The OMR feature accepts all valid EBCDIC characters. Validity checking for mark reading is identical with the validity checking used for hole reading.

The other standard read checking circuits are not used for OMR. Marks are read only once, but three check circuits test for correct operation. These three checks are as follows:

*Undefined Mark Check:* Checks the quality of the marks. Poor marks or bad erasures or dirt cause "read checks" and are not read as valid marks. (See also Appendix B.)

*No Area Check:* Checks that at least one mark read area is recognized when the card is defined as OMR card by a valid identification code in front of column 1.

*Any Cell Error:* Checks the proper function of the 12 OMR data photo-cells. All three checks cause read-check errors and are indicated on the console by the standard read-check light.

A switch is provided behind the front cover, for Customer Engineer (CE) use only, that permits the undefined mark check to be suppressed.

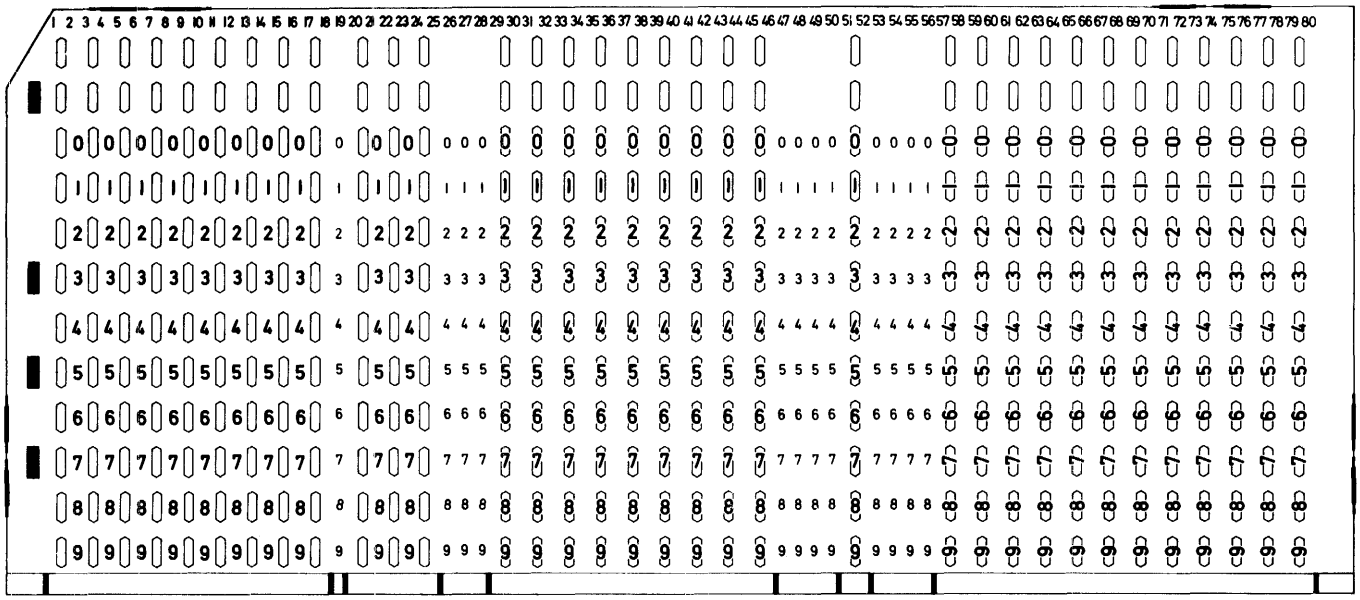


Figure 4. OMR Card [06504]

The sensitivity of the mark recognition is preset and is not adjustable by the operator. The Customer Engineer can change the mark recognition to a higher sensitivity, but this higher sensitivity may cause reading of erasures or dirt, therefore mark specifications are not available for this feature.

The specifications for OMR cards are summarized in Appendix A, together with a drawing of the card showing dimensions.

The card color must be white, natural, or any other color with sufficiently high reflectance. The average reflectance of the card stock must be 52 mV or more. All reflectance measurements are to be made with a Kidder Press Company Inc. Model MR 8 Optical Mark Read Tester or equivalent. The reflectance is indicated in millivolts (mV). A high reading indicates high reflectance, while a low reading indicates low reflectance. Average reflectance is defined as the average of three or more readings on the test instrument at different locations on the card.

A black printed mark combination 11-3-5-7 in front of column 1 is necessary for OMR card recognition (Figure 4). No other dark printing is permitted in front of column 1. If standard cards with dark printing in front of column 1 are to be read by an OMR machine, these may possibly be mistaken for OMR cards. To avoid this confusion by the recognition circuits, an identification code other than 11-3-5-7 can be used on the OMR cards. The identification code recognition circuits can be altered accordingly by the CE. The division of the card OMR into mark read fields and punch fields is not restricted. Minimum field length is one column and a maximum of 40 mark read columns is possible. The beginning and the end of a mark read field is indicated by black printed control marks below the 9 punch row, therefore other dark printing in this area is permitted. The identification and control marks must have an average reflectance of 25 mV or less.

The position of a mark in a mark read field is determined by a preprinted hexagonal marking outline (marking constraint). The marking constraint and any other printing in a mark read field must have an average reflectance of 95% to 100% of the average reflectance of the card stock.

Any blemishes or dirt within a mark read field with less reflectance may cause read checks. Orange or any other color meeting the above requirements may be used for printing in mark read fields. OMR cards must not be perforated or have punch holes in the OMR fields. Corner cuts are not allowed on the left-hand 9-edge corner. C1, C2, and C3 corner cuts (Figure 5) are permitted on both 12-edge corners and a C3 corner cut is also allowed on the right-hand 9-edge. Round corners are allowed on all four corners.

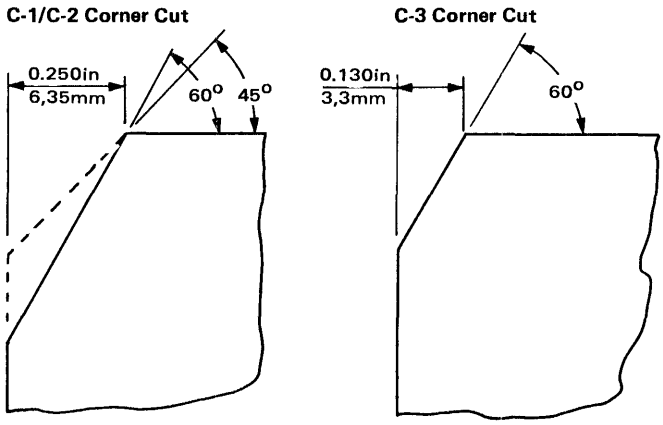



Figure 5. OMR Card – Acceptable Cuts [06505]

## MARKS

Marks can be made with an ordinary No. 2 or HB black lead pencil or any other pencil of comparable medium hardness and good blackness. Clean erasures are permitted, but incomplete erasures may cause read checks or may be read as marks.

Marks must be made as heavy vertical strokes, and they must be at least as long as the constraint length (Figure 6). Longer marks are permitted if they do not extend into the area of the next upper or lower constraint or reach into the control mark area on the 9-edge. Mark width must be between 0.016 in (0,4 mm) and 0.055 in (1,4 mm). At least 0.016 in (0,4 mm) of the mark must be within the marking constraint for the full length of the constraint.

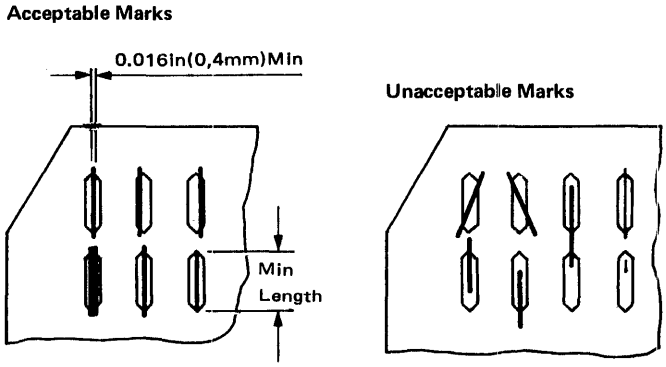



Figure 6. OMR Card – Acceptable Marks [06506]

Because the interface to the processor on the 2501 Models B1 and B2 is different from that on the 2501 Models A1 and A2 and the 2560 Models A1 and A2, there are also differences in the data transmission concept.

### 2501 MODELS B1 AND B2

Although one mark column requires the space of two punch columns, the mark column produces only one data byte. The data bytes are stored consecutively in the lower part of the read-in area. In applications with intermixed reading of OMR and standard cards in undefined sequence, the length count in the read instruction should cover the maximum input record length. When an OMR card with reduced number of data is read, the read-in area is not completely filled and the length count in the instruction is not reduced to zero. The wrong length indicator must be ignored by the program. The instruction will be terminated by the input device with a normal input/output (I/O) channel ending sequence and the read-in area may contain old data in its upper part. The timing specifications given for the standard machines are still valid with OMR, but the data rate is divided by two while reading marks. The average time between two data bytes is doubled because only every second timing pulse is used for mark reading. The timing for a complete read cycle is unchanged.

### 2501 MODELS A1 AND A2, 2560 MODELS A1 AND A2

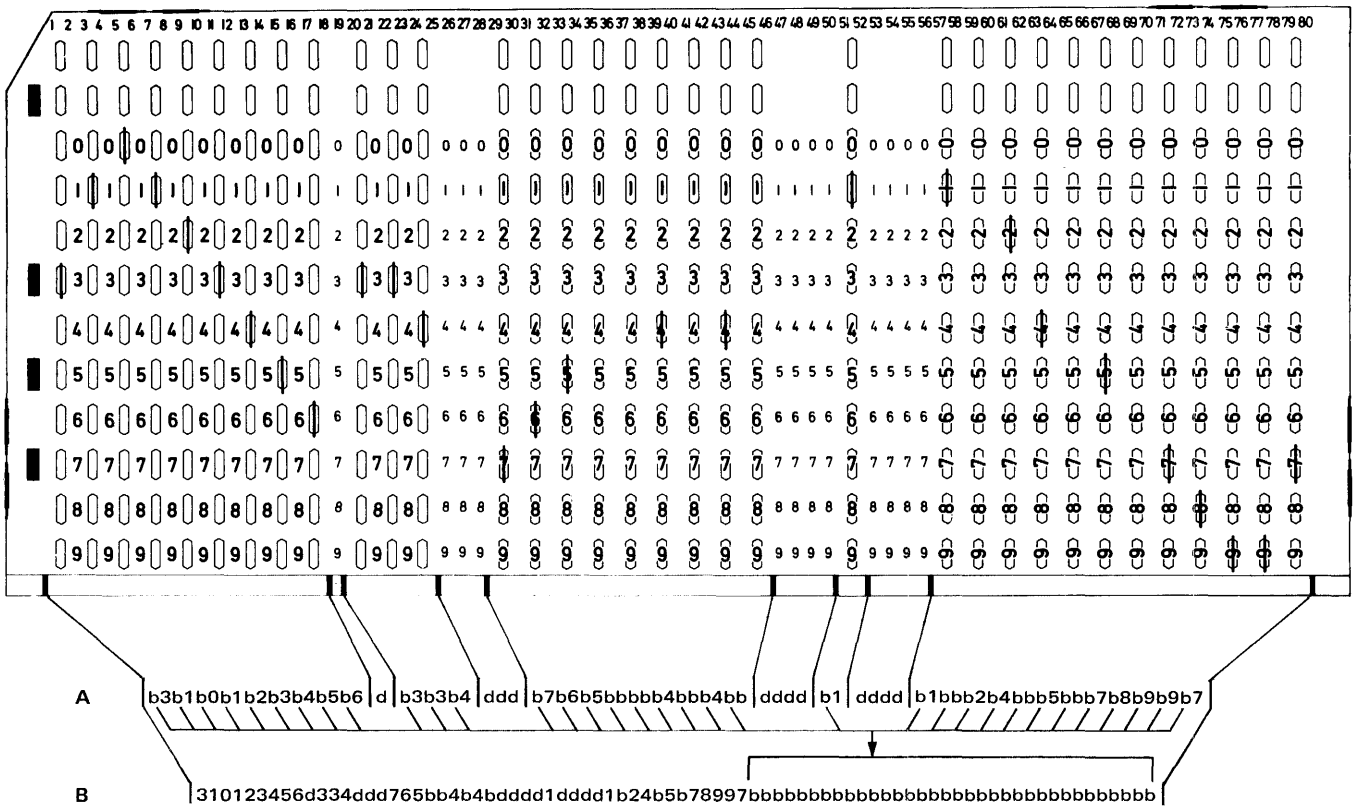
These machines are not able to terminate a read instruction by themselves after a card has been read. The ending procedure is initiated by the processor when the specified length count in the read instruction has been reduced to zero. The length count must always be 80 bytes. To maintain proper instruction ending procedure, the data transmission concept of the 2501 Models B1 and B2 cannot be used. In applications with intermixed reading in undefined sequence, a length count which is not reduced to zero would cause a program hangup, because a termination of the instruction would never occur. The 2501 Models A1 and A2 and the 2560 therefore produce two data bytes per mark column. The first byte is a blank character, the second is the marked character. Each mark read card produces 80 characters irrespective of the number of mark columns on the card. Each mark column requires two storage bytes. Marked data read from a card is positioned in storage as blank data, blank data, blank data (see Figure 7).

The user can easily write a small program subroutine to change this byte arrangement after it has been stored in core. It is only necessary to take out the blanks and to compress the data field. If writing or usage of such subroutines causes difficulties, a modification on RPQ basis in the IBM 2020 Processing Unit can be installed. This modification makes the OMR feature fully compatible with RPG and Utility Program.

With this RPQ installed the 2020 Processing Unit separates the incoming extra blanks from the OMR fields and places them at the right end of the read-in area. Blank mark columns produce normal blanks in storage and marked columns produce normal data bytes not separated by blanks. This modification in the 2020 is not included in the OMR feature and must be ordered separately for the 2020. The timing specification given for standard machines 2501 Models A1 and A2 and 2560 is unchanged and is also completely valid for optical mark reading.

A Data in storage

B Data in storage if additional RPQ for 2020 is installed




b = Blank

d = Standard Punched Data

Figure 7. Arrangement of Data Storage [06507]

### ELIMINATION OF OMR FUNCTION ON ROWS 12 AND 11

This feature allows black printing in rows 12 and 11. The OMR function is restricted to rows 0 through 9. Rows 12 and 11 are eliminated over the entire length of the card.

### SWITCH OFF OMR

This RPQ allows OMR cards to be read as standard punch cards. In some applications, readout of the punched data on an OMR card is required only, or the card may contain holes within the OMR field. These holes would produce an inaccurate readout. To prevent an inaccurate readout occurring because holes are present in the OMR field, an illuminated pushbutton is provided on the operator panel to switch off the OMR function. Recognition and reading of marks is operative with the pushbutton light on and inoperative when the light is off.

Neither feature is included in the OMR feature and each must be ordered separately for the particular machines.

### REFERENCE LISTING RPQ NUMBERS

The following list (Figure 8) shows the RPQ numbers for the OMR and companion features. Availability, prerequisites, limitations, and prices of the OMR and companion features should be checked with the Special Equipment Engineering Department in the country concerned via the local IBM representative.

| RPQ N° | Name | Machine |
|---|---|---|
| Y91070 | Optical Mark Read Head | All |
| Y91080 | Optical Mark Reading | 2501 A1, A2 |
| Y12168 | Optical Mark Reading | 2501 B1, B2 |
| Y39504 | Optical Mark Reading | 2560 A1 |
| Z21902 | Optical Mark Reading | 2560 A2 |
| Y91213 | OMR Elimination on Row 12 & 11 | 2501 A1 A2 B1 B2 (not on 1130 Sys.) |
| Y91214 | OMR Elimination on Row 12 & 11 | 2560 A1, A2 |
| Y91210 | OMR Elimination 12 & 11 Switch Control | 2560 A1, A2 |
| Y91235 | Switch off OMR | 2501 A1 A2 |
| Y08333 | Switch off OMR | 2501 B1 B2 |
| Y04973 | Switch off OMR | 2560 A1 A2 |

Figure 8. List of RPQ's [06508]

# Appendix A. OMR Card Design and Specifications

## GENERAL

### OMR Card

An OMR card is defined as a card having certain identification marks in front of column 1. These marks, which are shown in Figure 9, appear in the 11, 3, 5, and 7 rows.

### OMR Field

An OMR field consists of a minimum of 1 and a maximum of 40 OMR columns. An OMR field starts and ends with a control mark. Each OMR column occupies the space of two punch columns. The remaining area on the card occupied by columns not used for OMR is defined as punch field(s). All OMR cards must have at least one OMR field defined by control marks; a check will result during reading if no OMR field is found.

### Control Mark

Control marks define the beginning and end of OMR fields on an OMR card. These marks appear along the 9-edge of the card and are shown in detail C of Figure 9.

### Marking Constraints

Marking constraints are preprinted hexagonal outlines defining the locations of marks.

## CARD STOCK

### General

The OMR cards must meet the normal specifications for unit record cards and, in addition, the following specifications:

### Color and Reflectance

Natural, white, or any other card stock having an average reflectance* of 52 mV or more may be used.

### Blemishes

Blemishes that appear in the OMR fields must reflect between 0.95 and 1.0 of the average reflectance of the particular card. For example, a card with an average reflectance of 52 mV must not have a blemish in an OMR field that reflects less than 0.95 X 52 mV = 49.4 mV or one that reflects more than 1.0 X 52 mV = 52 mV.

* All reflectance readings are to be made with a Kidder Press Company, Inc., Model MR8 Optical Mark Read Tester or equivalent. "Average reflectance" is defined as the average of three readings at three separate locations on the card using this test equipment.

### Scoring

The card must not be perforated (scored) in either the OMR fields or the punch fields.

### Corner Cuts

A corner cut is not permitted on the leading (left-hand) 9-edge. C1, C2, and C3 corner cuts are permissible on both 12-edge corners and a C3 cut is permissible on the trailing (right-hand) 9-edge corner. Round corners are allowed on all four corners.

## PRINTING

### Identification and Control Marks

The identification marks in column "0" and the control marks along the 9-edge must be printed in black with a reflectance of 25 mV or less. Any other printing in the areas specified by note 10 of Figure 9 (just behind the leading edge and just above the 9-edge) must have an average reflectance between 0.95 and 1.0 times that of the particular card.

### Marking Constraints

Marking constraints must be printed in orange or other colors having an average reflectance between 0.95 and 1.0 of that of the particular card itself. All printing appearing in OMR fields (alphamerics, etc) must also have an average reflectance between 0.95 and 1.0 of that of the card. The marking constraints may contain numerals or other coding printed in the same ink as the constraint itself (see Figure 9 for examples). Dark printing on the upper edge of the card (Rows 11 and 12) is allowed if the reader to be used has the additional RPQ "OMR Elimination on Rows 12 and 11" or "OMR Elimination Switch for Rows 12 and 11". When these RPQ's are in operation no marks can be read in Rows 12 or 11.

### Punch Fields

Printing of any color is permitted within punch fields. Such printing must not extend past the outer edges of the control marks defining the OMR fields, nor into the area reserved for the identification and control marks.

## Glossary

*Control Marks:* are preprinted black marks on the 9-edge of the OMR card that indicate the beginning and end of an OMR field.

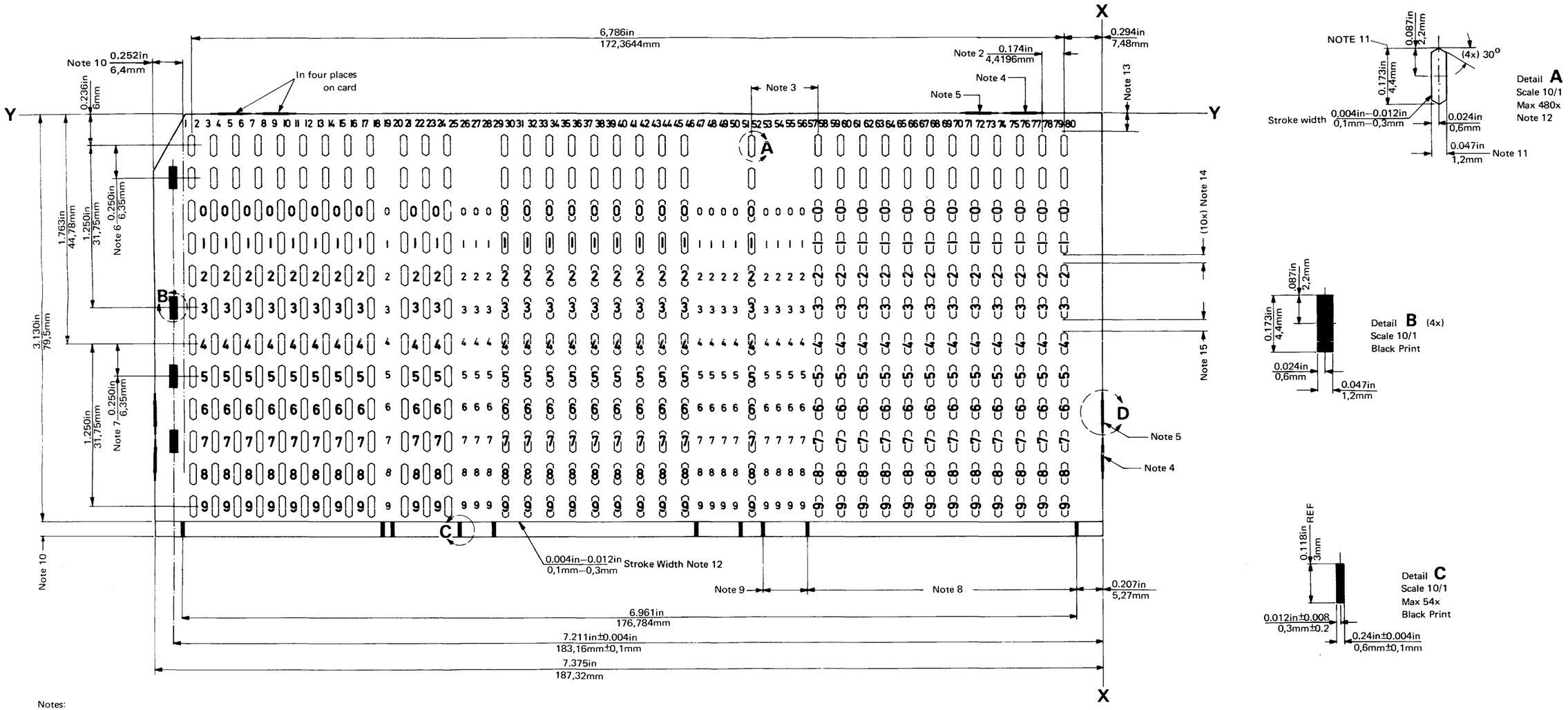
*Identification Marks:* are a pattern of rectangular black marks preprinted on the OMR card in front of column 1.

*Marking Constraints:* (position guides) are hexagonal frames on the OMR card determining the proper position of the marks.

*OMR (Optical Mark Read) Card:* is an especially designed card used for mark reading with this feature.

*OMR Field:* is an area on the OMR card that contains one or more mark columns.

*Punch Field:* is an area on the OMR card that contains one or more punch columns.



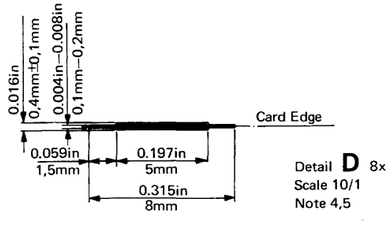













Notes:

1. Cards must be printed according to Appendix A
2. Up to 39 spaces at 0.174in (4,4196mm) may vary 0.006in (0,15mm) from X–X
3. 0.174in (4,4196mm) plus 0.087in (2,2098mm) times number of punch columns. Tolerance ±0.006 (0,15mm) from X–X
4. Bleed lines used for identification mark printing
5. Bleed lines used for constraint printing
6. Five spaces at 0.25in (6,35mm) may vary ±0.006in (0,15mm) from Y–Y
7. Five spaces at 0.25in (6,35mm) may vary ±0.006in (0,15mm)
8. 0.174in (4,4196mm) times number of mark read columns. Tolerance the same as in Note 2
9. 0.087in (2,2098mm) times number of punch columns. Tolerance the same as in Note 2
10. See "Identification and Control Marks" under "PRINTING" in Appendix A
11. Dimension applies to outer edge of stroke
12. See "Marking Constraints" under "PRINTING" in Appendix A
13. Dark printing maximum 0.142in (3,6mm) in height is permissible
14. Dark printing maximum 0.067in (1,6mm) in height is permissible
15. Dark printing maximum (0,094mm) in height is permissible

Figure 9. OMR Card – Identification Marks [06509]

## Appendix B. Undefined Mark Check

A special checking feature, Undefined Mark Check (UMC) has been built into the OMR RPQ's for the 2501 and 2560. This appendix explains the reasons for this check and its basic principles of operation.

Automatic optical readers should give the same results as a human would. This ideal case is seldom achieved in practice since the recognition procedure is primitive compared to the human eye.

The ideal mark can be defined as a straight, vertical stroke having a certain height, a certain width and a certain degree of blackness. In practice, a multiplicity of marks appear: crooked, angled, smeared, short and long, wide and narrow.

Tests on OMR-recognition equipment have shown that very weak, thin, straight marks produce the same digital results as very intense, broad, but angled marks or poor erasures or dark smudges. The last two possibilities prohibit an unlimited increase in amplification of the analog signals in order to recognize poor marks.

Thus the requirement for an intermediate zone arises. This zone should include all analog signals where it cannot be clearly determined whether they represent marks, erasures, or dirt. Therefore, the recognition circuits should have, in addition to "Yes" (mark) and "No" (no mark, dirt, or erasure) outputs, a "Perhaps" output. This "Perhaps" output is the Undefined Mark Check in the OMR feature.

### UNDEFINED MARK CHECK OPERATION

The analog signal is compared with two thresholds. The crossing points determine the beginning and end of two digital signals. The less sensitive (higher threshold) digital signal is designated "LO-signal" and the more sensitive (lower threshold) is "HI-signal". When the LO-signal is used for a "Yes-No" indication and the HI-signal for the "Perhaps", the following logical table results:

| *LO* | *HI* | *OUTPUT* | *CAUSE* |
|---|---|---|---|
| X | X | Yes | Mark |
| | | No | No Mark |
| | X | Perhaps | Mark, Erasure, Dirt |
| X | | Error | Hardware Failure |

The logic in the OMR-feature is designed so that the LO-signal is transmitted to the CPU as data and the combination of the HI- and LO-signals is sent to the "Read-Check" latch through an exclusive-OR circuit. This technique makes it possible to recognize a defective amplifier, because the combination LO, NOT HI can only occur as a result of a hardware error.

The UMC-region is defined as the "Perhaps" combination. By varying the threshold levels the UMC-region can be enlarged or reduced. Because the "Perhaps" output is used mainly to select out doubtful marks to be manually checked it is desirable that as few as possible "Read Checks" be obtained. To achieve this the UMC-region should be as small as possible, but there is a risk when too narrow a region is chosen that poor marks will not be discovered.

It can be seen from the preceding paragraph that the UMC should indicate weak marks (have a large region) and not be triggered by erasures or dirt (have a small region). These two conflicting requirements must be balanced one against the other.

In the OMR Feature the relationship is set at:

LO : HI = 1 : 1.33

This ratio takes the following criteria into consideration:

1. *Adjustment of lamp voltage:*
   The lamp voltage can be set by the customer engineer between 2.6 and 3.0 volts. This represents a variation in the analog signal of 52% in relation to 2.6V, and means that a mark, which at 2.6V is just detectable, can be read perfectly when barely 2.9V.
2. *Recognition of bad marks caused by erasures and dirt:*
   Dirty areas having a large area with unsharp edges are suppressed by an RC filter. The UMC needs only to take care of dirty areas having a small area or sharp edges.

Practical experience with UMC has shown that marks are easily recognized at 2.6V. Straight, vertical, thin, very weak marks are not recognized; however, these do produce an Undefined Mark Check. The same occurs with intense marks when these are either very angled or are too short. Erasures are *not* recognized as marks at 2.6V. Very poor erasures cause an UMC. At higher lamp voltages, some poor erasures are recognized as marks, and at lamp voltages of 2.8 to 3.0 volts, a third of the erasures lead to UMC's. Careful erasures, however, are not recognized as marks nor do they cause UMC's. The UMC region chosen shows the best compromise: a larger region would cause too many "Read Checks" resulting from dirt and erasures, at 2.6V on the lamp, and a smaller region would not select out doubtful marks.

The Undefined Mark Check provides the user of the OMR feature with a facility for checking the quality of the marks during the reading process. Should too many UMC's occur, measures can be taken to improve the quality of the marks before they become so poor that they cause incorrect data to be read. Tests have shown that the quality of the marks depends primarily on the training of the marking personnel; when the marks become so poor that they cause UMC's, a reminder must be given to the personnel concerned to mark the cards more carefully.

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