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Kishi

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(45) **Date of Patent: Nov. 19, 2013**

(54) **STORAGE SYSTEM, AND ENCRYPTION KEY MANAGEMENT METHOD AND ENCRYPTION KEY MANAGEMENT PROGRAM THEREOF**

(75) Inventor: **Masayuki Kishi**, Hiratsuka (JP)

(73) Assignees: **Hitachi, Ltd.**, Tokyo (JP); **Hitachi Computer Peripherals Co., Ltd.**, Kanagawa-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1333 days.

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(22) Filed: **Apr. 8, 2008**

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(30) **Foreign Application Priority Data**

Jan. 31, 2008 (JP) 2008-020325

(51) **Int. Cl.**
G06F 11/00 (2006.01)
H04L 9/00 (2006.01)

(52) **U.S. Cl.**
USPC **726/23**; 380/277

(58) **Field of Classification Search**
USPC 726/23; 380/277; 705/904; 713/194; 711/161, 162, 164
See application file for complete search history.

(56) **References Cited**

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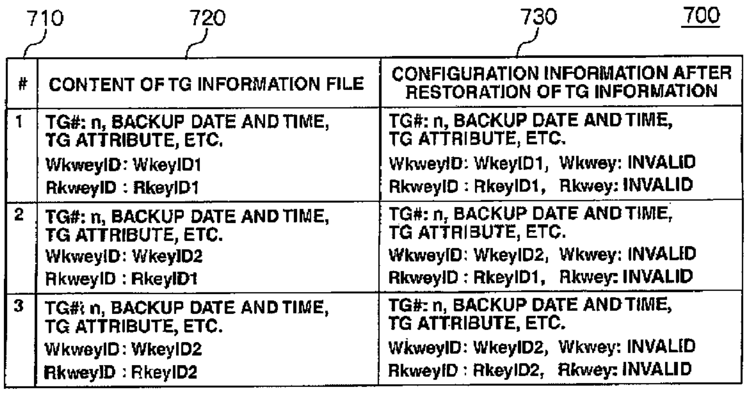
Primary Examiner — Eleni Shiferaw
Assistant Examiner — Abu Sholeman
(74) *Attorney, Agent, or Firm* — Stites & Harbison PLLC; Juan Carlos A. Marquez, Esq.; Nicholas B. Trenkle, Esq.

(57) **ABSTRACT**

A user no longer needs to restore key information upon restoring data. Proposed is a storage system having a storage apparatus, a tape library apparatus for backing up data stored in the storage apparatus, and a management terminal for managing the storage apparatus and the tape library apparatus. The management terminal identifies a key of a tape to be restored and restores a management Information file based an a tape management file, a tape group information file and a key information file upon restoring data stored in the tape in the tape library apparatus, and commands the restoration of the tape based on the restored management information file.

14 Claims, 17 Drawing Sheets


710
720
730
700

#	CONTENT OF TG INFORMATION FILE	CONFIGURATION INFORMATION AFTER RESTORATION OF TG INFORMATION
1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1 RkweyID : RkeyID1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID
2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2 RkweyID : RkeyID1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID
3	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2 RkweyID : RkeyID2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2, Wkwey: INVALID RkweyID : RkeyID2, Rkwey: INVALID

FIG.1

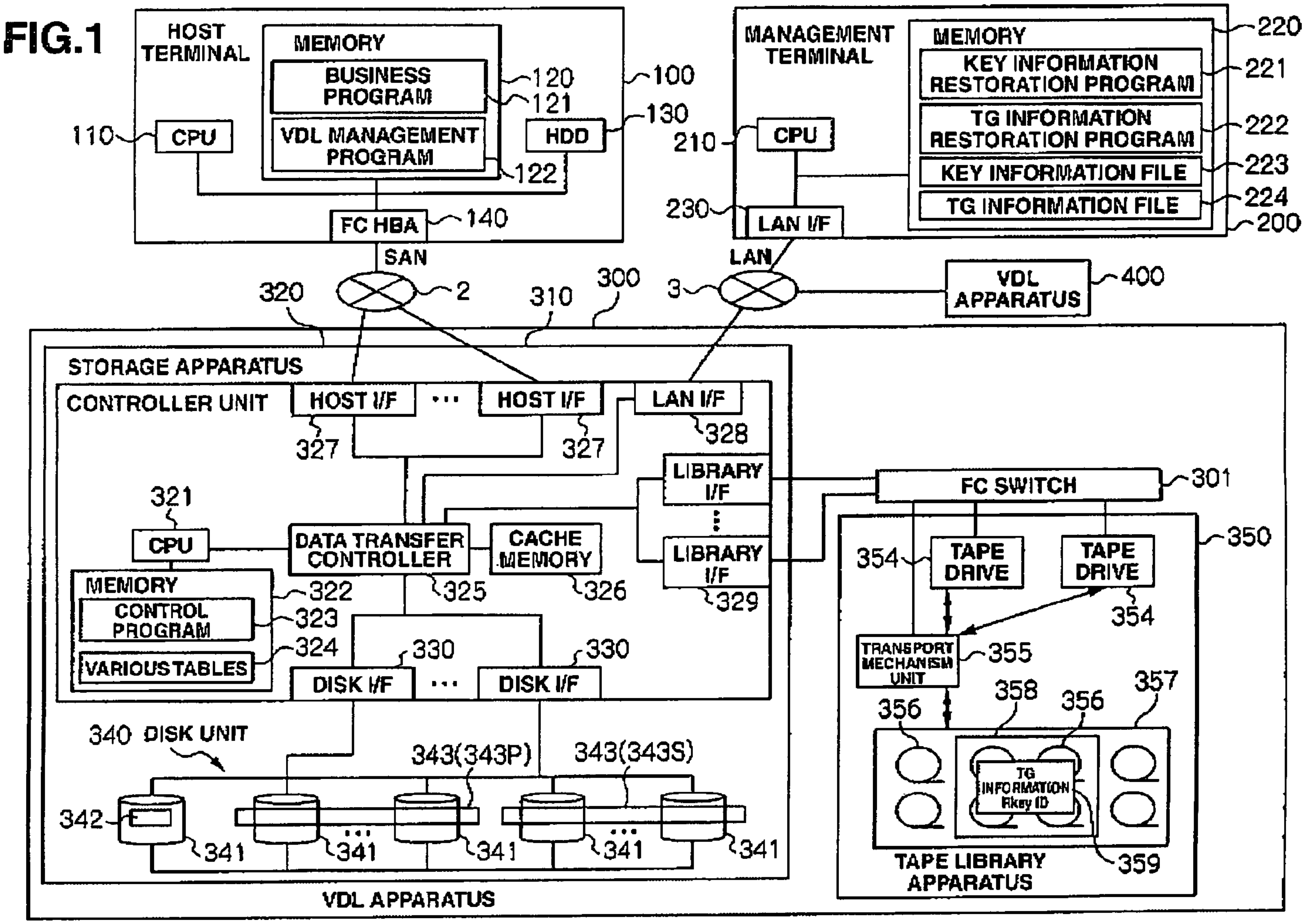

HOST TERMINAL
MEMORY
BUSINESS PROGRAM
VDL MANAGEMENT PROGRAM
CPU
HDD
FC HBA
110
120
121
122
100
130
140
SAN
2
320
310
300
MANAGEMENT TERMINAL
MEMORY
KEY INFORMATION RESTORATION PROGRAM
TG INFORMATION RESTORATION PROGRAM
KEY INFORMATION FILE
TG INFORMATION FILE
CPU
LAN I/F
210
230
220
221
222
223
224
200
LAN
3
VDL APPARATUS
400
STORAGE APPARATUS
CONTROLLER UNIT
HOST I/F
HOST I/F
LAN I/F
327
327
328
LIBRARY I/F
LIBRARY I/F
329
321
CPU
DATA TRANSFER CONTROLLER
CACHE MEMORY
MEMORY
CONTROL PROGRAM
VARIOUS TABLES
322
323
324
325
326
DISK I/F
DISK I/F
330
330
340 DISK UNIT
343(343P)
343(343S)
342
341
341
341
341
341
VDL APPARATUS
FC SWITCH
301
350
TAPE DRIVE
TAPE DRIVE
354
354
TRANSPORT MECHANISM UNIT
355
356
358
356
357
TG INFORMATION Rkey ID
359
TAPE LIBRARY APPARATUS

FIG.2

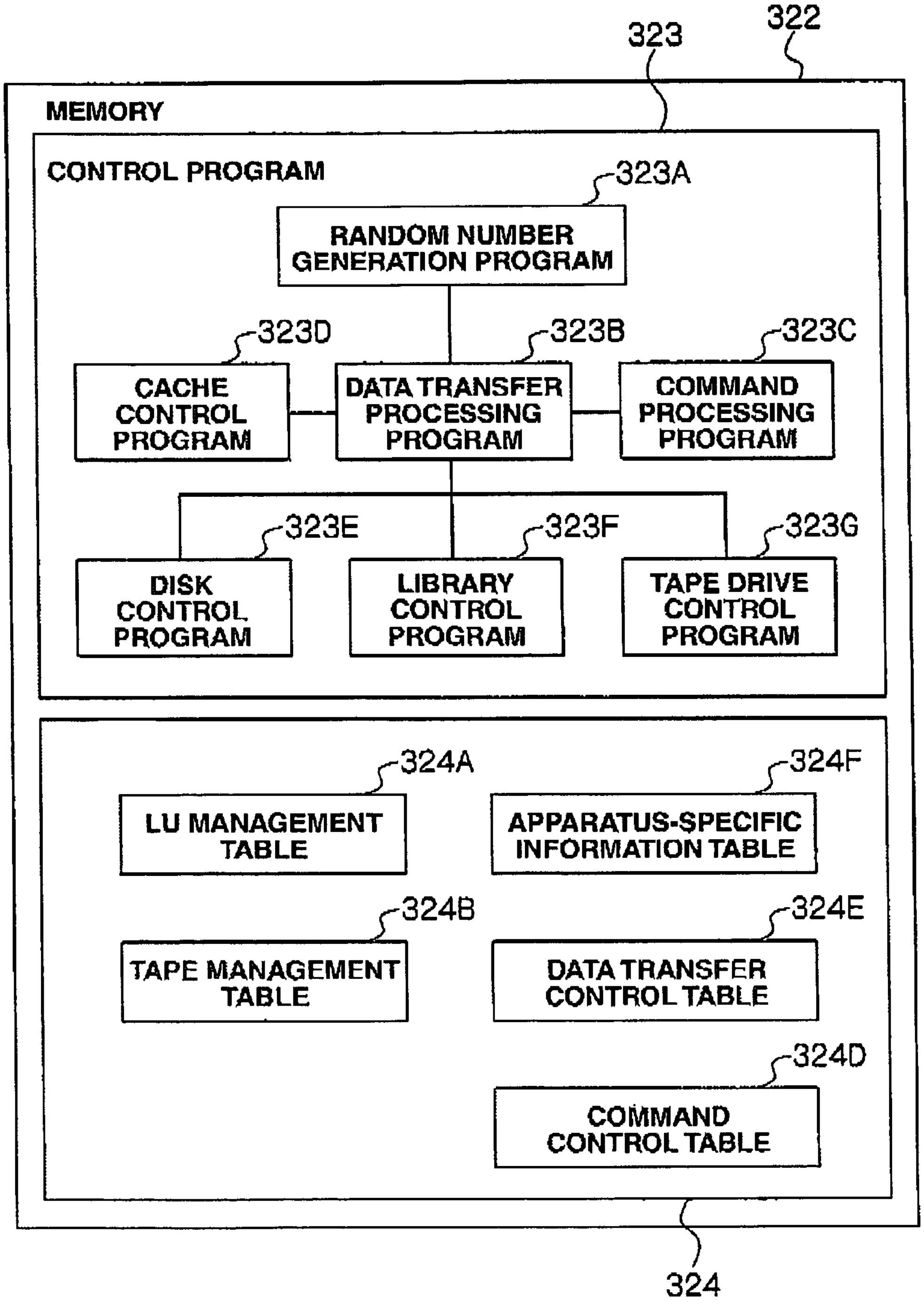

322
323
MEMORY
CONTROL PROGRAM
323A
RANDOM NUMBER GENERATION PROGRAM
323D
CACHE CONTROL PROGRAM
323B
DATA TRANSFER PROCESSING PROGRAM
323C
COMMAND PROCESSING PROGRAM
323E
DISK CONTROL PROGRAM
323F
LIBRARY CONTROL PROGRAM
323G
TAPE DRIVE CONTROL PROGRAM
324A
LU MANAGEMENT TABLE
324F
APPARATUS-SPECIFIC INFORMATION TABLE
324B
TAPE MANAGEMENT TABLE
324E
DATA TRANSFER CONTROL TABLE
324D
COMMAND CONTROL TABLE
324

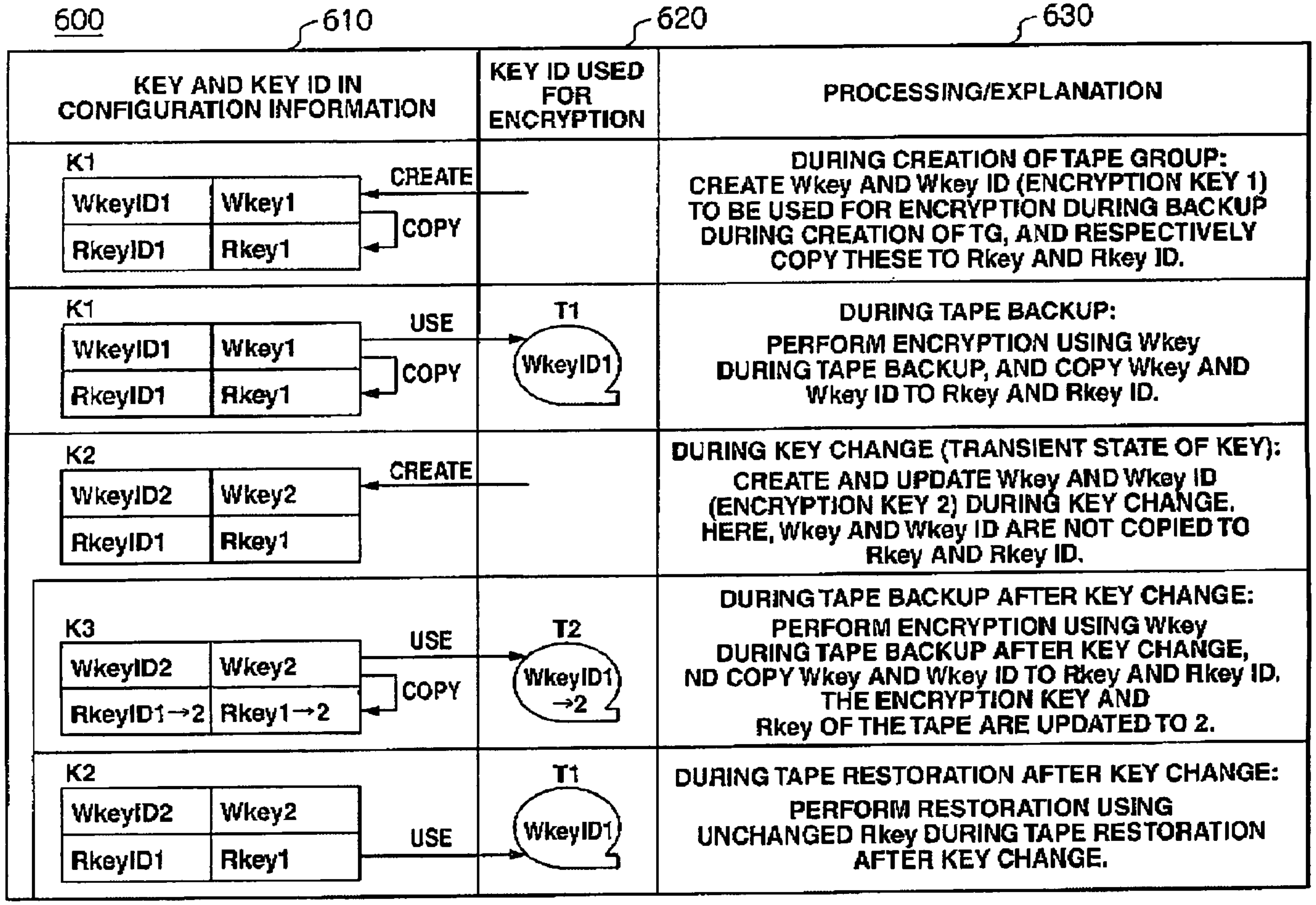
FIG.3

500

510 511 512 513 514 515 516 517 518 519 520 521 522 523

TG NUMBER	TG CLOSURE STATUS	TG COPY STATUS	MIRROR STATUS	USED TAPE NUMBER (PRIMARY)	USED TAPE NUMBER (SECONDARY)	STORED LU LIST	WRITE DATE AND TIME	KEYWORD	ENCRYPTION STATUS	WkeyID	RkeyID	Wkey	Rkey
0	NORMAL	COPY_END	ON	0, 1	2, 3	2, 4	2007/07/20 01:23:45	DB1_20070720	ON	20070718083015_0	20070718083015_0	****	****
1	SECONDARY CLOSURE	COPY_END	ON	4, 5	6, 7	2, 4	2007/07/19 01:23:45	DB1_20070719	ON	20070719170045_0	20070718083015_0	%%%%	****
2	NORMAL	COPY_END	OFF	9		10, 11, 12	2007/07/20 05:55:55	DB2_20070720	ON	20070719170045_0	20070719170045_0	%%%%	%%%%
3	NORMAL	COPY_END	OFF	8		20, 21	2007/07/20 03:33:33	DB3_20070720	OFF	INVALID	INVALID	INVALID	INVALID

FIG.4



KEY AND KEY ID IN CONFIGURATION INFORMATION	KEY ID USED FOR ENCRYPTION	PROCESSING/EXPLANATION
K1 WkeyID1 | Wkey1 RkeyID1 | Rkey1 CREATE COPY		DURING CREATION OF TAPE GROUP: CREATE Wkey AND Wkey ID (ENCRYPTION KEY 1) TO BE USED FOR ENCRYPTION DURING BACKUP DURING CREATION OF TG, AND RESPECTIVELY COPY THESE TO Rkey AND Rkey ID.
K1 WkeyID1 | Wkey1 RkeyID1 | Rkey1 USE COPY	T1 WkeyID1	DURING TAPE BACKUP: PERFORM ENCRYPTION USING Wkey DURING TAPE BACKUP, AND COPY Wkey AND Wkey ID TO Rkey AND Rkey ID.

K2
WkeyID2 | Wkey2
RkeyID1 | Rkey1
CREATE
		DURING KEY CHANGE (TRANSIENT STATE OF KEY):
		CREATE AND UPDATE Wkey AND Wkey ID (ENCRYPTION KEY 2) DURING KEY CHANGE. HERE, Wkey AND Wkey ID ARE NOT COPIED TO Rkey AND Rkey ID.

K3 WkeyID2 | Wkey2 RkeyID1→2 | Rkey1→2 USE COPY	T2 WkeyID1 →2	DURING TAPE BACKUP AFTER KEY CHANGE: PERFORM ENCRYPTION USING Wkey DURING TAPE BACKUP AFTER KEY CHANGE, ND COPY Wkey AND Wkey ID TO Rkey AND Rkey ID. THE ENCRYPTION KEY AND Rkey OF THE TAPE ARE UPDATED TO 2.
K2 WkeyID2 | Wkey2 RkeyID1 | Rkey1 USE	T1 WkeyID1	DURING TAPE RESTORATION AFTER KEY CHANGE: PERFORM RESTORATION USING UNCHANGED Rkey DURING TAPE RESTORATION AFTER KEY CHANGE.

FIG.5

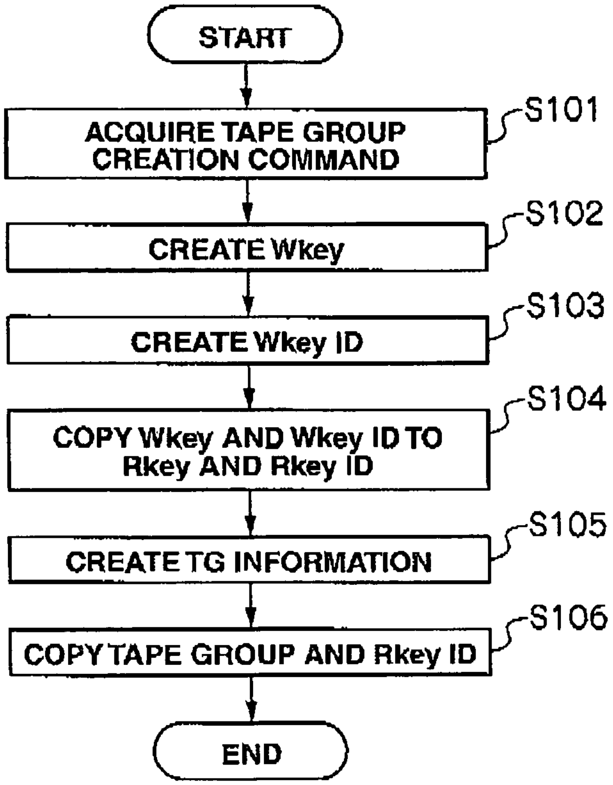

START
ACQUIRE TAPE GROUP CREATION COMMAND
S101
CREATE Wkey
S102
CREATE Wkey ID
S103
COPY Wkey AND Wkey ID TO Rkey AND Rkey ID
S104
CREATE TG INFORMATION
S105
COPY TAPE GROUP AND Rkey ID
S106
END

FIG.6

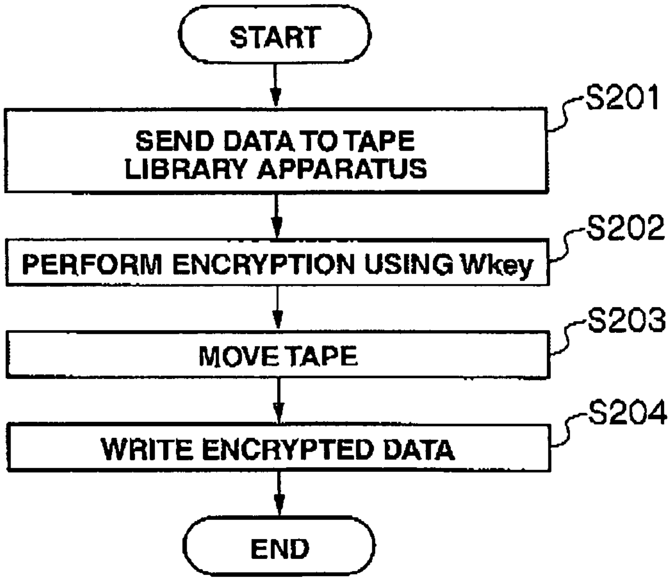

START
SEND DATA TO TAPE LIBRARY APPARATUS
S201
PERFORM ENCRYPTION USING Wkey
S202
MOVE TAPE
S203
WRITE ENCRYPTED DATA
S204
END

FIG.7

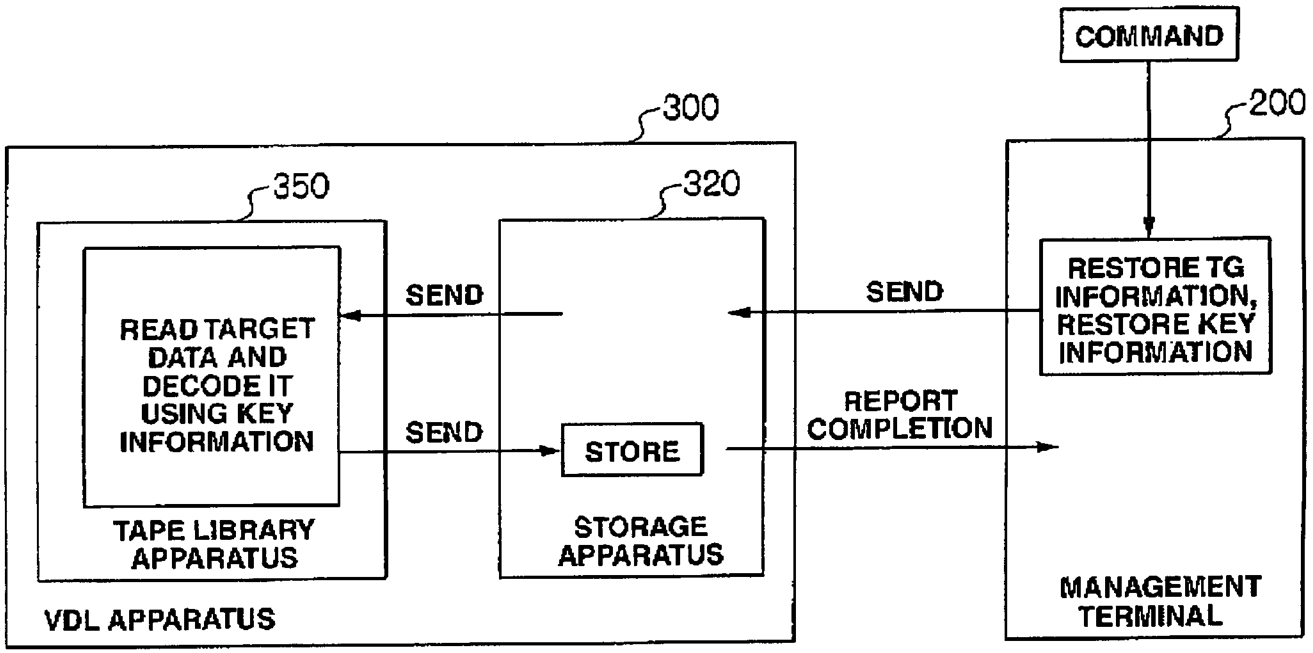

COMMAND
200
RESTORE TG INFORMATION, RESTORE KEY INFORMATION
MANAGEMENT TERMINAL
SEND
REPORT COMPLETION
300
320
STORE
STORAGE APPARATUS
SEND
SEND
350
READ TARGET DATA AND DECODE IT USING KEY INFORMATION
TAPE LIBRARY APPARATUS
VDL APPARATUS

FIG.8

710 720 730 700

#	CONTENT OF TG INFORMATION FILE	CONFIGURATION INFORMATION AFTER RESTORATION OF TG INFORMATION
1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1 RkweyID : RkeyID1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID
2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2 RkweyID : RkeyID1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID
3	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2 RkweyID : RkeyID2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2, Wkwey: INVALID RkweyID : RkeyID2, Rkwey: INVALID

FIG.9

810 820 830 840 800

#	CONFIGURATION INFORMATION AFTER RESTORATION OF TG INFORMATION	CONTENT OF KEY INFORMATION FILE	CONFIGURATION INFORMATION AFTER RESTORATION OF KEY INFORMATION
1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID1, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID (Status of #1 in FIG. 8)	TG#: n WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1
2		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID3, Wkwey : Wkwey3 RkweyID : RkeyID1, Rkwey : Rkwey1
3		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2	KEY INFORMATION RESTORATION IS NOT POSSIBLE
4	TG#: n WkweyID : WkeyID2, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID (Status of #2 in FIG. 8)	TG#: n WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID3, Wkwey : Wkwey3 RkweyID : RkeyID1, Rkwey : Rkwey1
5		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1
6		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2	KEY INFORMATION RESTORATION IS NOT POSSIBLE
7	TG#: n WkweyID : WkeyID2, Wkwey: INVALID RkweyID : RkeyID2, · Rkwey: INVALID (Status of #3 in FIG. 8)	TG#: n WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1	KEY INFORMATION RESTORATION IS NOT POSSIBLE
8		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2
9		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2

FIG.10

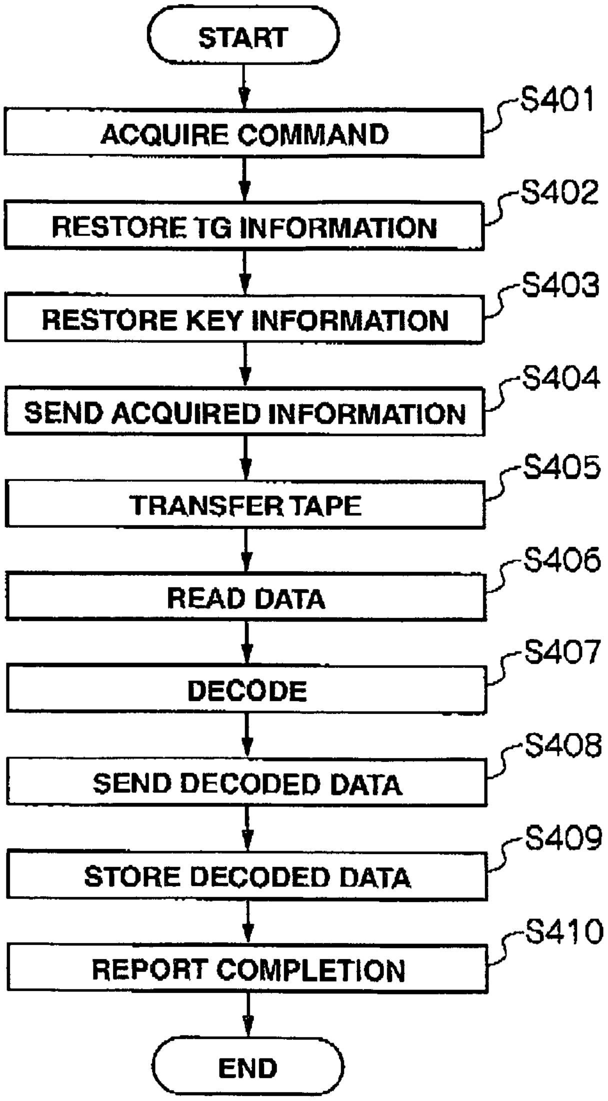

START
ACQUIRE COMMAND
S401
RESTORE TG INFORMATION
S402
RESTORE KEY INFORMATION
S403
SEND ACQUIRED INFORMATION
S404
TRANSFER TAPE
S405
READ DATA
S406
DECODE
S407
SEND DECODED DATA
S408
STORE DECODED DATA
S409
REPORT COMPLETION
S410
END

FIG.11

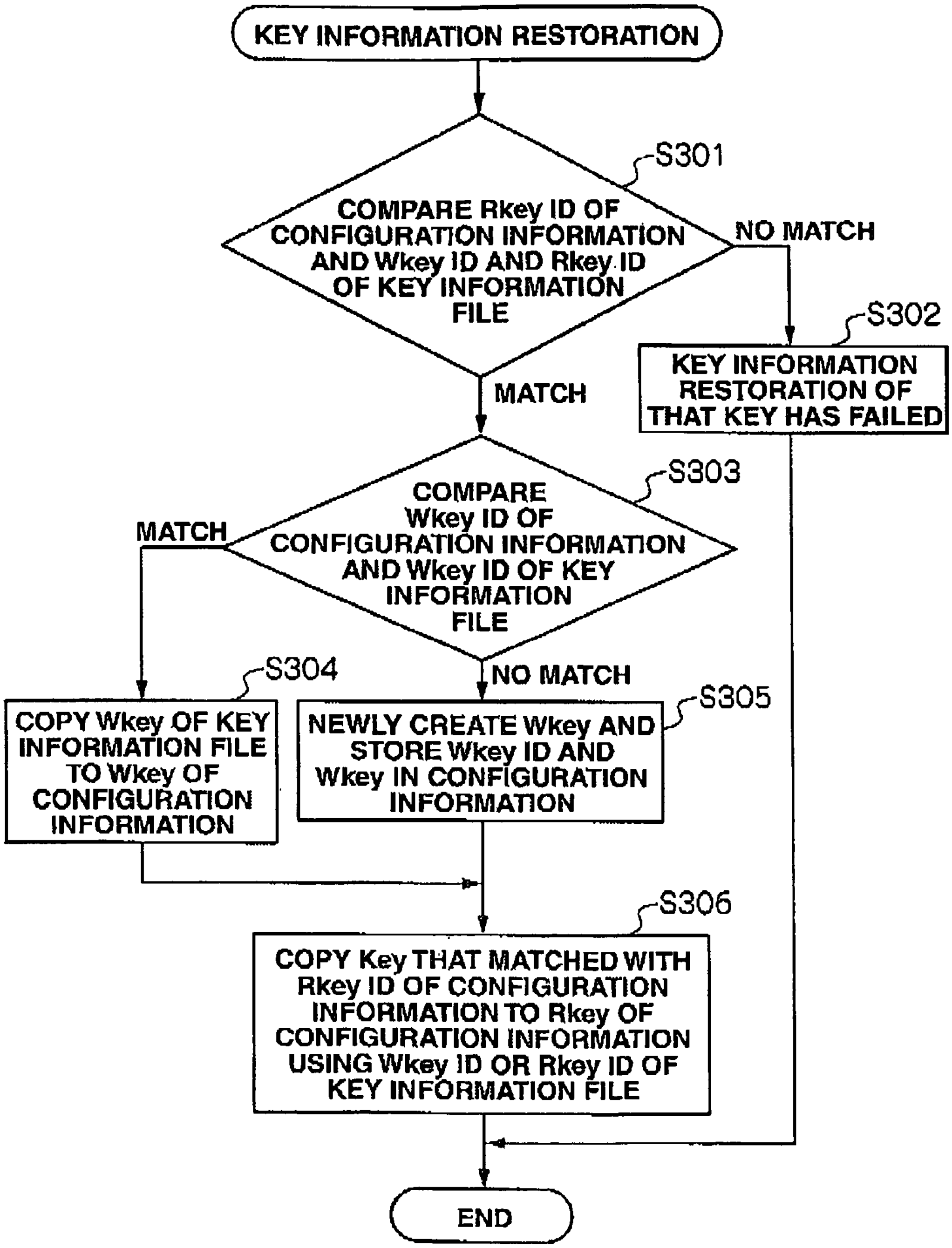

KEY INFORMATION RESTORATION
S301
COMPARE Rkey ID OF CONFIGURATION INFORMATION AND Wkey ID AND Rkey ID OF KEY INFORMATION FILE
NO MATCH
S302
KEY INFORMATION RESTORATION OF THAT KEY HAS FAILED
MATCH
S303
COMPARE Wkey ID OF CONFIGURATION INFORMATION AND Wkey ID OF KEY INFORMATION FILE
MATCH
NO MATCH
S304
COPY Wkey OF KEY INFORMATION FILE TO Wkey OF CONFIGURATION INFORMATION
S305
NEWLY CREATE Wkey AND STORE Wkey ID AND Wkey IN CONFIGURATION INFORMATION
S306
COPY Key THAT MATCHED WITH Rkey ID OF CONFIGURATION INFORMATION TO Rkey OF CONFIGURATION INFORMATION USING Wkey ID OR Rkey ID OF KEY INFORMATION FILE
END

FIG.12

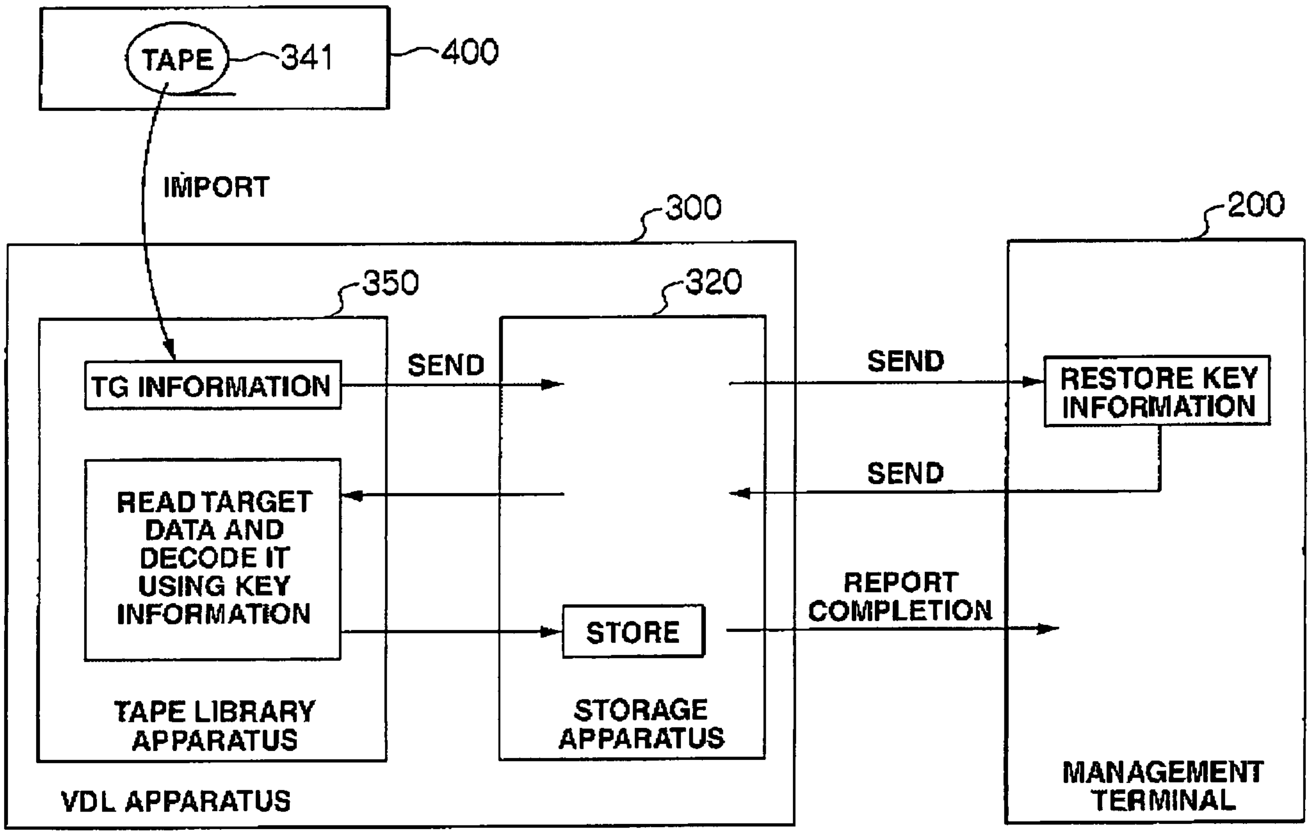
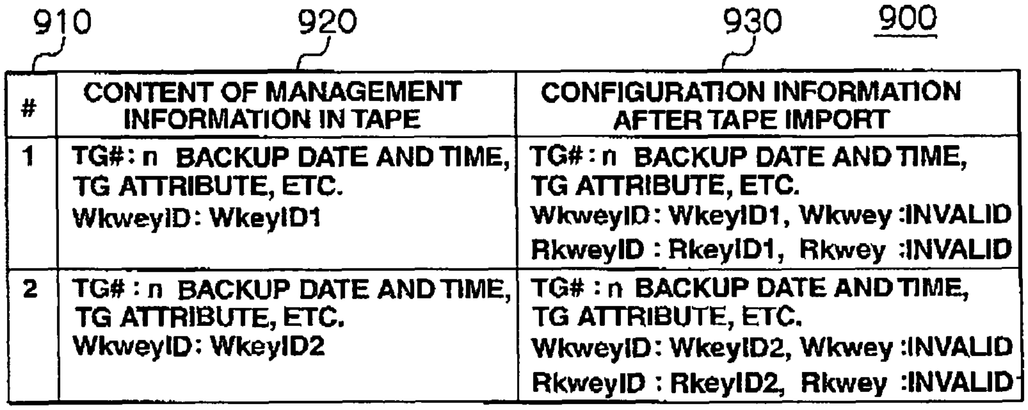

TAPE
341
400
IMPORT
300
200
350
320
TG INFORMATION
SEND
SEND
RESTORE KEY INFORMATION
READ TARGET DATA AND DECODE IT USING KEY INFORMATION
SEND
STORE
REPORT COMPLETION
TAPE LIBRARY APPARATUS
STORAGE APPARATUS
MANAGEMENT TERMINAL
VDL APPARATUS

FIG.13


910
920
930
900

#	CONTENT OF MANAGEMENT INFORMATION IN TAPE	CONFIGURATION INFORMATION AFTER TAPE IMPORT
1	TG#: n BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1	TG#: n BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1, Wkwey :INVALID RkweyID : RkeyID1, Rkwey :INVALID
2	TG# : n BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2	TG# : n BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID2, Wkwey :INVALID RkweyID : RkeyID2, Rkwey :INVALID

FIG.14

1010 1020 1030 1040 1000

#	CONFIGURATION INFORMATION AFTER TAPE IMPORT	CONTENT OF KEY INFORMATION FILE	CONFIGURATION INFORMATION AFTER RESTORATION OF KEY INFORMATION
1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID: WkeyID1, Wkwey: INVALID RkweyID : RkeyID1, Rkwey: INVALID (Status of #1 in FIG. 13)	TG#: n WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1
2		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID3, Wkwey : Wkwey3 RkweyID : RkeyID1, Rkwey : Rkwey1
3		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2	KEY INFORMATION RESTORATION IS NOT POSSIBLE
4	TG#: n WkweyID : WkeyID2, Wkwey: INVALID RkweyID : RkeyID2, Rkwey: INVALID (Status of #2 in FIG. 13)	TG#: n WkweyID : WkeyID1, Wkwey : Wkwey1 RkweyID : RkeyID1, Rkwey : Rkwey1	KEY INFORMATION RESTORATION IS NOT POSSIBLE
5		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID1, Rkwey : Rkwey1	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2
6		TG#: n WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2	TG#: n, BACKUP DATE AND TIME, TG ATTRIBUTE, ETC. WkweyID : WkeyID2, Wkwey : Wkwey2 RkweyID : RkeyID2, Rkwey : Rkwey2

FIG.15

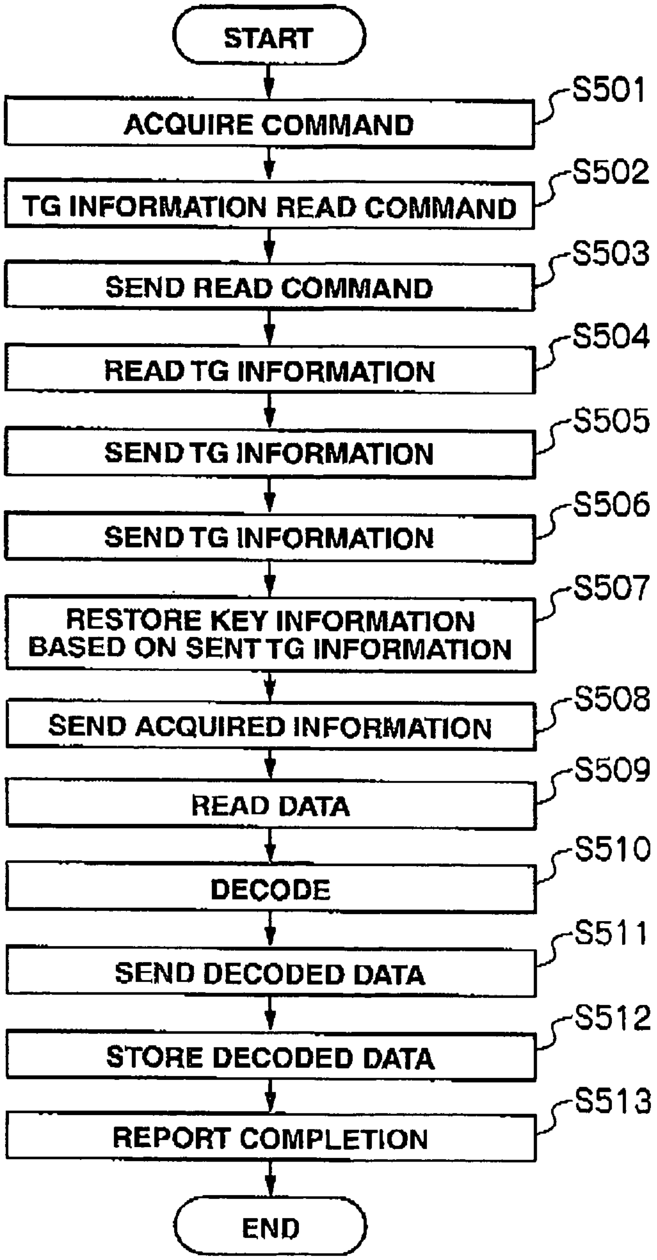

START
ACQUIRE COMMAND
S501
TG INFORMATION READ COMMAND
S502
SEND READ COMMAND
S503
READ TG INFORMATION
S504
SEND TG INFORMATION
S505
SEND TG INFORMATION
S506
RESTORE KEY INFORMATION BASED ON SENT TG INFORMATION
S507
SEND ACQUIRED INFORMATION
S508
READ DATA
S509
DECODE
S510
SEND DECODED DATA
S511
STORE DECODED DATA
S512
REPORT COMPLETION
S513
END

FIG.16

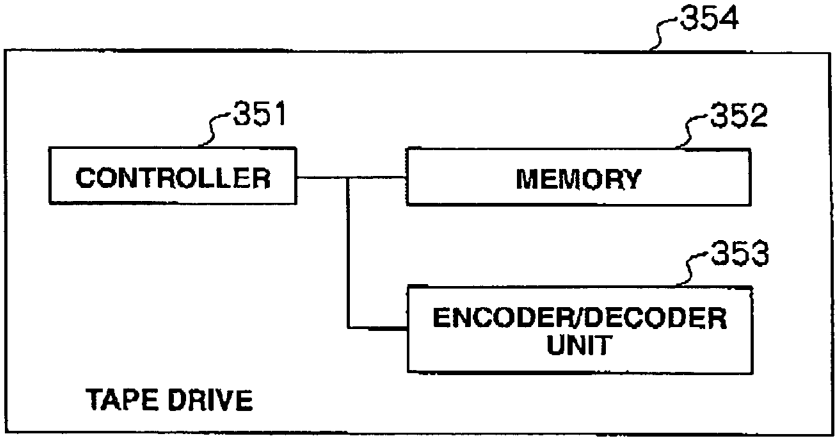

354
351
CONTROLLER
352
MEMORY
353
ENCODER/DECODER UNIT
TAPE DRIVE

FIG.17

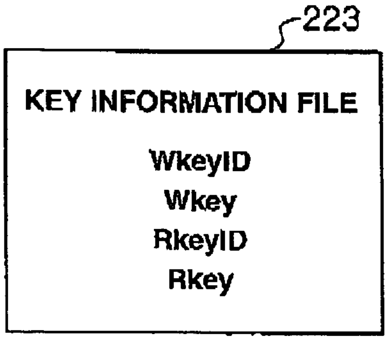
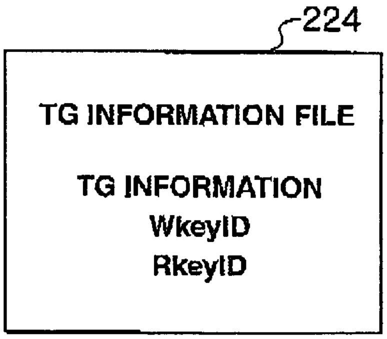

223
KEY INFORMATION FILE
WkeyID
Wkey
RkeyID
Rkey

FIG.18


224
TG INFORMATION FILE
TG INFORMATION
WkeyID
RkeyID

STORAGE SYSTEM, AND ENCRYPTION KEY MANAGEMENT METHOD AND ENCRYPTION KEY MANAGEMENT PROGRAM THEREOF

CROSS-REFERENCES

This application relates to and claims priority from Japanese Patent Application No 2008-020325, filed on Jan. 31, 2008, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

The present invention generally relates to a storage system and its encryption key management method and encryption key management program. In particular, the present invention can be suitably applied to a storage system that manages an encryption key for restoring data stored on a tape, and to its encryption key management method and encryption key management program.

Technology is known for controlling the reading and writing of electronic information using an encryption key upon storing such electronic information in a storage medium (for instance, refer to Japanese Patent Laid-Open Publication No. 2004-341768 and Japanese Patent Laid-Open Publication No. 2003-244131). With a tape apparatus, measures are taken to prevent the loss or leakage of tape, or to prevent the decryption of encrypted data in the tape pursuant to users' needs by periodically changing the apparatus-side encryption key.

When restoring data from a tape, assuming that a key corresponding to the storage apparatus with a tape function has been changed, data cannot be restored from the tape since the data encryption key will not match. Thus, it is necessary to return the key to the state before change, and there is "key information backup/restoration" as a method for achieving the above. This method is used for the user to back up key information in the system disk of the storage apparatus, or to restore the key to the state before change from the backed up key information.

SUMMARY

Nevertheless, the "key backup/restoration" method requires the management of data (file) before and after the key change, and is complicated in that it requires the user's operation. Moreover, in light of the process from "change of key" to "backup to tape," when restoring the configuration information of such transient state, there is a problem in that the user will not know whether the operation to be performed after the restoration of the configuration information is tape backup based on a post-change key or tape restoration based on a pre-change key.

The present invention was devised in view of the foregoing problems. Thus, an object of the present invention is to provide a storage system and its encryption key management method and encryption key management program that does not require a user to restore key information upon restoring data.

Thus, the present invention provides a storage system comprising a storage apparatus, a tape library apparatus for backing up data stored in the storage apparatus, and a management terminal for managing the storage apparatus and the tape library apparatus. The storage apparatus includes a key creation unit for creating a first key for encrypting data upon backing up data in a tape of the tape library apparatus, a first key ID of the first key, a second key for decrypting data that

was encrypted with the first key, and a second key ID of the second key, and a management information file for associating management information concerning data with the created first key, first key ID, second key, and second key ID upon backing up the data in the storage apparatus to a tape in the tape library apparatus. The tape library apparatus includes a data processing unit for encrypting data using the first key ID upon writing data into the tape, and decrypting data of the tape using the second key ID upon reading data from the tape. The tape includes a tape management file containing at least the first key ID and the second key ID among the management information. The management terminal includes a tape group information file for backing up information containing the first key ID and the second key ID stored in the management information file, a key information file for backing up the first key, the first key ID, the second key and the second key ID stored in the management information file, a key information processing unit for identifying a key of a tape to be restored and restoring the management information file based on the tape management file, the tape group information file and the key information file upon restoring data stored in the tape in the tape library apparatus, and a command unit for commanding the restoration of the tape based on the management information file restored with the key information processing unit.

According to the present invention, it is possible to propose a storage system and its encryption key management method and encryption key management program that does not require a user to restore key information upon restoring data.

DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram showing the configuration of a storage system according to the present invention;

FIG. **2** is a diagram showing the contents stored in a memory according to the present invention;

FIG. **3** is a diagram showing the contents stored in a tape group information table according to the present invention;

FIG. **4** is a transition diagram showing the transition of the change in state of a key and key ID according to the present invention;

FIG. **5** is a flowchart showing tape group creation processing according to the present invention;

FIG. **6** is a flowchart showing processing to be performed during tape backup according to the present invention;

FIG. **7** is a view showing a frame format briefly explaining data restoration using TG information restoration processing and key information restoration processing according to the present invention;

FIG. **8** is a state diagram showing the status of the key and key ID after restoration of the TG information based on TG information restoration under the preconditions based on the transition diagram according to the present invention;

FIG. **9** is a state diagram showing the status of the key and key ID restored based on key information restoration after the TG information restoration according to the present invention;

FIG. **10** is a flowchart showing restoration processing for restoring data using TG information restoration processing and key information restoration processing according to the present invention;

FIG. **11** is a flowchart showing key information restoration processing according to the present invention;

FIG. **12** is a view showing a frame format briefly explaining data restoration using key information restoration processing after tape import according to the present invention;

FIG. **13** is a state diagram showing the status of the key and key ID after restoration of TG information via tape import under the preconditions based on the transition diagram according to the present invention;

FIG. **14** is a state diagram showing the status of the key and key ID restored based on key information restoration after TG information restoration according to the present invention;

FIG. **15** is a flowchart showing restoration processing for restoring data using key information restoration processing after performing tape import according to the present invention;

FIG. **16** is a diagram showing the internal configuration of a tape drive according to the present invention;

FIG. **17** is a diagram showing the contents stored in a key information file according to the present invention; and

FIG. **18** is a diagram showing the contents stored in a tape group information file according to the present invention.

DETAILED DESCRIPTION

Technology is known for controlling the reading and writing of electronic information using an encryption key upon storing such electronic information in a storage medium. With a tape apparatus, measures are taken to prevent the loss or leakage of tape, or to prevent the decryption of encrypted data in the tape pursuant to users' needs by periodically changing the apparatus-side encryption key.

When restoring data from a tape, assuming that a key corresponding to the storage apparatus with a tape function has been changed, data cannot be restored from the tape since the data encryption key will not match. Thus, it is necessary to return the key to the state before change. But since this method is used for the user to back up key information in the system disk of the storage apparatus, or to restore the key to the state before change from the backed up key information, this method requires the management of data (file) before and after the key change, and is complicated in that it requires the user's operation. Moreover, in light of the process from "change of key" to "backup to tape," when restoring the configuration information of such transient state, there is a problem in that the user will not know whether the operation to be performed after the restoration of the configuration information is tape backup based on a post-change key or tape restoration based on a pre-change key.

Thus, the present invention is able to perform tape restoration after the key change, without the user restoring key information, by retaining the two types of data encryption keys of Wkey and Rkey explained in the following embodiment in a storage system configured from a management terminal, and a storage apparatus with a tape apparatus.

Embodiments of the present invention are now explained with reference to the attached drawings. Incidentally, the embodiments explained below are not intended to limit the scope of the appended claims in any way, and the entire combination of features explained in the embodiments are not necessarily required as the means for solving the problems of the present invention.

FIG. **1** is a diagram showing the configuration of a storage system **1** according to the present invention.

The storage system **1** includes a host terminal **100**, a management terminal **200**, a VDL apparatus **300**, and a VDL apparatus **400**. The host terminal **100** and the VDL apparatus **300** are connected via a SAN (Storage Area Network) **2**. The management terminal **200** is connected respectively to the VDL apparatuses **300**, **400** via a LAN (Local Area Network) **3**. Although the VDL apparatus **400** is shown to be connected only to the LAN **3**, the configuration may be such that it is also connected to the host terminal **100**, or connected to another host terminal. The number of host terminals and VDL apparatuses is not limited to the quantity shown in FIG. **1**, and the storage system **1** may be configured by including two or more host terminals and three or more VDL apparatuses.

The host terminal **100** includes a CPU **110**, a memory **120**, an HDD (Hard Disk Drive) **130**, and an FC HBA (Fiber Channel Host Bus Adapter) **140**. The CPU **110**, the memory **120**, the HDD **130** and the FC HBA **140** are mutually connected. The memory **120** stores a business program **121**, and a VDL apparatus management program **122**. The business program **121** is a program for issuing a write request or a read request of data to the VDL apparatus **300**. The VDL apparatus management program **122** is a program for managing the mirroring, backup processing, restoration processing and so on of data by the VDL apparatus **300**.

The CPU **110** realizes the functions of the business program **121** and the VDL apparatus management program **122** by reading and executing the business program **121** and the VDL apparatus management program **122**.

The management terminal **200** includes a CPU **210**, a memory **220**, and a LAN I/F **230**. The CPU **210**, the memory **220**, and the LAN I/F **230** are mutually connected. The memory **220** stores, in addition to well-known programs for managing the VDL apparatus **300**, a key information restoration program **221** and a TG information restoration program **222**, and additionally stores a key information file **223** and a TG (tape group) information file.

The CPU **210** realizes the functions of the key information restoration program **221** and the TG information restoration program **222** by reading and executing the key information restoration program **221** and the TG information restoration program **222**. The key information restoration program **221** is a program for causing the CPU **210** to execute key information restoration, and the TG information restoration program **222** is a program for causing the CPU **210** to execute TG information restoration, and these programs will be explained in detail later. Information to be stored in the key information file **223** and the TG information file **224** will also be explained later.

The VDL apparatus **300** is a storage apparatus equipped with a tape read/write function, and is configured by the storage apparatus **310** and the tape library apparatus **350** being connected to an FC (Fiber Channel) switch **301**.

The storage apparatus **310** includes a controller unit **320** and a disk unit **340**. The controller unit **320** includes a CPU **321**, a memory **322**, a data transfer controller **325**, a cache memory **326**, a plurality of host I/Fs **327**, a LAN I/F **328**, a plurality of library I/Fs **329**, and a plurality of disk I/Fs **330**. The data transfer controller **325** and the CPU **321**, memory **322**, cache memory **326**, host I/Fs **327**, LAN I/F **328** and disk I/Fs **330** are connected mutually, and the library I/Fs **330** are connected to the cache memory **326**.

The CPU **321** controls the VDL apparatus **300** by executing the programs stored in the memory **322**. The memory **322** stores various control programs **322** and various tables **324**. The various control programs **322** and the various tables **324** stored in the memory **322** will be described later with reference to FIG. **2**. The host I/F **327** controls the exchange of data between the controller unit **320** and the host terminal **100**. The LAN I/F **328** controls the exchange of data between the controller unit **320** and the management terminal **200**. The library I/F **329** controls the exchange of data between the controller unit **320** and the tape library apparatus **350**. The data transfer controller **325** controls the exchange of data among the host terminal **100**, the management terminal **200**, the disk drive **341**, the tape library apparatus **350**, the cache memory **326** and the CPU **321**. The cache memory **326** temporarily stores data and the like that are exchanged among the host terminal **100**, the management terminal **200**, and the disk drive **341**. The disk I/F **330** controls the exchange of data between the controller unit **320** and the disk unit **340**.

The disk unit **340** includes a plurality of disk drives **341**. These disk drives **341** are connected to a plurality of disk I/Fs **330**. The plurality of disk drives **341** are set with volumes in LU (Logical Units). Data is made redundant between a primary volume **343**P and a secondary volume **343**S configured from prescribed LUs. One disk drive among the plurality of disk drives **341** configures a system disk for storing configuration information **342**. The configuration information **342** will be explained later with reference to FIG. **3**. Incidentally, although a case was explained with only one system disk storing the configuration information **342** in FIG. **1**, redundancy can be retained by configuring the system disk from a plurality of disk drives **341**.

The tape library apparatus **300** includes a plurality of tape drives **354**, a transport mechanism unit **355**, a tape **356**, and a tape storage unit **357**. The plurality of tape drives **354** and the transport mechanism unit **355** are connected to the FC switch **301**.

The tape drive **354** reads data from the tape **356**, or writes data on the tape **356**. The tape drive **354** is now explained in detail with reference to FIG. **16**. As shown in FIG. **16**, the tape drive **354** includes a controller **351**, a memory **352** and an encoder/decoder unit **353**. The controller **351** comprehensively controls the tape drive **354**. The memory **352** temporarily stores key information and the like used for the encryption and decryption of data. The encoder/decoder unit **353** encodes data using the key information stored in the memory **352** upon writing data onto the tape **356** transported into the tape drive **354**, and decodes data using the key information stored in the memory **352** upon reading data from the tape **356** transported into the tape drive **354**.

The transport mechanism unit **355** transports the tape **356** of a designated tape group to the tape drive **354**, and transports the tape **356** from the tape drive **354** to the tape storage unit **357**. The tape storage unit **359** stores a plurality of tapes **356**. The tape **356** stores information such as the TG information containing information showing the tape group, and key information (Rkey ID described later) for decrypting data. For example, the tape group **359** is configured from four tapes **356**.

Since the VDL apparatus **400** is configured the same as the VDL apparatus **300**, the illustration and detailed explanation of the internal configuration of the VDL apparatus **400** are omitted.

The various programs **323** and various tables **324** stored in the memory **322** of the storage apparatus **310** are now explained with reference to FIG. **2**.

As shown in FIG. **2**, the memory **322** stores, as the various programs **323**, a random number generation program **323**A, a data transfer processing program **323**B, a command processing program **323**C, a cache control program **323**D, a disk control program **323**E, a library control program **323**F, and a tape drive control program **323**G. The memory **322** additionally stores, as the various tables **323**, an LU (Logical Unit) management table **324**A, a tape management table **324**B, a command control table **324**D, an apparatus-specific Information table **324**F, and a data transfer control table **324**E.

The random number generation program **323**A is a program for causing the CPU **321** to control the generation of a random number to be used upon creating key information.

The command processing program **323**C is a program for causing the CPU **321** to interpret a command received from the host terminal **100** and a command received from the management terminal **200**, and control the corresponding processing.

The data transfer processing program **323**B is a program for causing the CPU **321** to control the transfer of data.

The cache control program **323**D is a program for causing the CPU **321** to temporarily cache the data to be read from or written into the cache memory **326**, and to control the reading or writing of such data.

The disk control program **323**E is a program for causing the CPU **321** to control the writing of data into the disk drive **341** and the reading of data from the disk drive **341**.

The tape drive control program **323**F is a program for causing the CPU **321** to control the data drive **354** for writing data onto the tape **356**, and reading data from the tape **356**.

The library control program **323**G is a program for causing the CPU **321** to control the transport mechanism unit **355** for transporting the tape **356** stored In the tape storage unit **357** to the tape drive **354**, and for transporting the tape **356** from the tape drive **354** to the tape storage unit **367**.

The LU management table **324**A and the tape management table **324**B are tables for managing the storage area of data and the like, and the command control table **324**D and the data transfer control table **324**E are tables for managing the storage of data and the like. Since the LU management table **324**A, the tape management table **324**B, the command control table **324**D and the data transfer control table **324**E are not directly related to the present invention, the detailed explanation thereof is omitted.

The apparatus-specific information table **324**F is a table for storing apparatus-specific information to be used upon creating key information. For example, apparatus-specific information would be the serial number of the storage apparatus **310**, a prescribed date and time, a sequence number, and the combinations thereof. When using unique information such as a serial number that is normally stored in the apparatus as the key information, such information shall be used, and the apparatus-specific information table **324**F may be omitted from the configuration.

FIG. **3** is a diagram showing the configuration information table storing the configuration information **343**. As shown in FIG. **3**, the configuration information table **500** includes a TG number column **510**, a TG closure status column **511**, a TG copy status column **512**, a mirror status column **513**, a used tape number (primary) column **514**, a used tape number (secondary) column **515**, a stored LU list column **516**, a write date and time column **517**, a keyword column **518**, an encryption status column **519**, a Wkey ID column **520**, an Rkey ID column **521**, a Wkey column **522**, and an Rkey column **523**.

The TG number column **510** stores the TG number that uniquely shows the tape group to become the storage unit for storing data. The TG closure status column **511** stores Information showing whether the corresponding TG is closed, normal or undefined. The TG copy status column **512** stores information of the status concerning TG copy. The mirror status column **513** stores information showing whether the corresponding TG is of a mirror status; that is, whether data is being stored redundantly. The used tape number (primary) column **514** stores the tape number of the tap **356** belonging to the TG. The used tape number (secondary) column **515** stores the tape number of the secondary tape **356** when the TG is of a mirror status. The stored LU list column **516** stores a list of the LU numbers of the volumes backed up to the corresponding TG The write date and time column **517** stores the date and time that the data was written into the TG. The keyword column **518** stores an arbitrarily set keyword. The encryption status column **519** stores information regarding whether the data has been encrypted.

For example, according to the first record, the TG number Is of a “0” status, the TG closure status is of a “normal” status, the TG copy status is of a “COPY_END” status, the used tape number (primary) is of a “0, 1” status, the used tape number (secondary) is of a “2, 3” status, the stored LU list is of a “2, 4” status, the write date and time Is of a “Jul. 7, 2007 01:23:45” status, the keyword is of a “DB1__20070720” status, the encryption status is of an “ON” status, the Wkey ID is of a “20070718083015__0” status, the Rkey ID is of a “20070718083015__0” status, the Wkey is of a “****” status, and the Rkey is of a “****” status. Incidentally, “****” shows an encrypted status.

The Wkey ID column **520**, the Rkey ID column **521**, the Wkey column **522** and the Rkey column **523** are columns for storing key information. Details concerning the Wkey ID, the Rkey ID, the Wkey and the Rkey to be stored therein will be explained later.

The flow of data backup in a conventional VDL apparatus is now explained. Data when the business program **121** of the host terminal **100** is executed is stored in the primary volume **343**P via the FC HBA **140**, the SAN **2**, the host I/F **327**, the data transfer controller **325**, and the disk I/F **330**. Data written into the primary volume **343**P of the storage apparatus **310** is written into the secondary volume **323**S at a prescribed timing, and the data is made redundant thereby. Subsequently, the data is backed up to the tape **356** of the tape library apparatus **350** via the disk I/F **330**, the data transfer controller **325**, the library I/F **329**, and the FC switch **301**.

The flow of data restoration in a conventional VDL apparatus is now explained. For example, when data to be read by the management terminal **200** is designated, the tape **356** written with such data is transported to the tape drive **354** with the transport mechanism unit **355**. The data read from the tape **356** to the tape drive **354** is written into the secondary volume **343**S via the FC switch **301**, the library I/F **329**, the data transfer controller **325**, and the disk I/F **330**. The data written into the secondary volume **343**S is reverse-copied to the primary volume **343**P. The intended data can thereby be restored.

In the ensuing explanation, upon backing up or restoring data in the VDL apparatus **300**, or upon importing tape to another VDL apparatus **400**, data is encrypted and decrypted upon backing up such data using an encryption key. The following explains the data processing using an encryption key in the VDL apparatus **300**.

The encryption key to be used for encrypting data is foremost explained. Specifically, with respect to this encryption key, a Wkey is created using a random number generated with the random number generation program **223**A, encrypted using the apparatus-specific information in the apparatus-specific information **224**F, and thereafter stored in the configuration information table **500**. Thus, when the Wkey is to be read from the configuration information table **500**, it is decrypted with the apparatus-specific information and then read. The Wkey is used upon writing (backing up) data onto the tape. In addition, the Wkey is copied to the Rkey during the creation or backup of the tape group. The Rkey is used as a decryption key upon reading (restoring) data. This Rkey is also encrypted with the apparatus-specific information, stored in the configuration information table **500**, and, when it is to be read, decrypted with the apparatus-specific information and then read.

During the creation of the Wkey, a Wkey ID that is unique among all VDL apparatuses (VDL apparatuses **300**, **400** in this embodiment) is created, and the Wkey ID is copied as the Rkey ID when the Wkey is copied to the Rkey. The timing to of creating the Wkey and the Wkey ID, and the timing of copying to the Rkey and the Rkey ID will be described later with reference to FIG. **4**. With respect to the encryption key, when the management terminal **200** issues a command for changing the encryption key, the processing for creating the encryption key is executed once again in the storage apparatus **310**, and a new Wkey and Wkey ID are created And the new Wkey and Wkey ID are copied as the Rkey and Rkey ID upon backing up the data.

Changes to the Wkey, the Wkey ID, the Rkey and the Rkey ID stored in the configuration information table **500** during the creation of a tape group, during tape backup, during key change, and during restoration are now explained. FIG. **4** is a transition diagram showing the changes of the foregoing statuses.

As shown in FIG. **4**, the transition diagram **600** includes a column **610** showing the key and key ID in the configuration information, a column **620** showing the key used in the encryption, and a column **630** showing the processing/explanation, and, in order from the first row at the top to the fifth row at the bottom, shows the status of the keys (Wkey, Rkey) and key IDs (Wkey ID, Rkey ID) during the creation of a tape group, during tape backup, during key change (transient state of key), during tape backup after key change, and during tape restoration after key change.

In FIG. **4**, Wkey **1** and Rkey **1**, Wkey ID **1** and Rkey ID **1**, Wkey **2** and Rkey **2**, and Wkey ID **2** and Rkey ID **2** are respectively equivalent, K**1** to K**3** show the status of key information, and T**1** and T**2** show the status of the key ID in the tape.

The case of “during creation of tape group” in the first row of the transition diagram **600** is now explained. The column **630** describes that the processing of “create Wkey and Wkey ID (encryption key 1) to be used for encryption during backup during creation of TG, and respectively copy these to Rkey and Rkey ID” will be performed. The column **620** is an empty column since an encryption key is not copied during the creation of the tape group. The column **610** shows a status where the Wkey **1** and the Wkey ID **1** are created as the status K**1** of the key, and these are copied as the Rkey and the Rkey ID **1**.

The case of “during tape backup” in the second row of the transition diagram **600** is now explained. The column **630** describes that the processing of “perform encryption using Wkey during tape backup, and copy Wkey AND Wkey ID to Rkey and Rkey ID” will be performed. The column **620** is a status where the Wkey ID **1** is stored as the status T**1** of the key in the tape. The column **610** shows a status where the status of the key is still the status K**1**, the Wkey **1** is to be used during the recording of data onto the tape, and the Wkey **1** and the Wkey ID **1** are copied as the Rkey **1** and the Rkey ID **1**.

The case of “during key change” in the third row of the transition diagram **600** is now explained. The column **630** describes that the processing of “create and update Wkey AND Wkey ID (encryption key 2) during key change. Here, Wkey and Wkey ID are not copied to Rkey AND Rkey ID” will be performed. The column **620** is an empty column since processing such as backup of data is not performed. The column **610** shows a status where the Wkey **2** and the Wkey ID **2** are created as the status K**2** of the key, and changed from the Wkey **1** and the Wkey ID **1**. The Rkey **1** and the Rkey ID **1** are still the same from the status K**1**.

The case of “during data backup after key change” in the fourth row of the transition diagram **600** is now explained. The column **630** describes that the processing of “perform encryption using Wkey during tape backup after key change, and copy Wkey and Wkey ID to Rkey and Rkey ID. The encryption key and Rkey of the tape are updated to 2" will be performed. The column **620** is a status where the Wkey ID **1** was changed to the Wkey ID **2** as the status T**2** of the key in the tape. The column **610** shows a status where the Wkey **2** and the Wkey ID **2** are copied as the Rkey **2** and the Rkey ID **2** as the status K**3** of the key.

The case of "during tape restoration after key change" in the fifth row of the transition diagram **600** is now explained. The column **630** describes that the processing of "perform restoration using unchanged Rkey during tape restoration after key change" will be performed. The column **620** stores the Wkey ID **1** as the status T**1** of the key in the tape. The column **610** shows the Wkey **2**, the Wkey ID **2**, the Rkey **1**, and the Rkey ID **1** as the status K**2** of the key information. Tape data is restored using this Rkey ID **1**.

FIG. **5** is a flowchart showing the processing to be performed during the creation of a tape group.

At step S**101**, the VDL apparatus **300** acquires a tape group creation command. This command is acquired by the VDL apparatus **300** as a result of prescribed operations being performed in the management terminal **200** and such command being sent from the management terminal **200** to the VDL apparatus **300**.

At step S**102**, the CPU **321** executes the random number generation program **323**A to generate a random number, and the created encryption key is the Wkey. The CPU **321** thereafter encrypts the Wkey using the apparatus-specific information stored in the apparatus-specific information table **324**F.

At step S**103**, the CPU **321** creates a Wkey ID with the Wkey created at step S**102** as the Wkey ID.

At step S**104**, the CPU **321** creates an Rkey and an Rkey ID by setting the Wkey created at step S**102** and the Wkey ID created at step S**103** respectively as the Rkey and the Rkey ID. The CPU **321** thereafter encrypts the Rkey using the apparatus-specific information stored in the apparatus-specific information table **324**F.

At step S**105**, the CPU **321** acquires other information including the created Wkey, Wkey ID, Rkey, and Rkey ID, and stores the acquired information in the configuration information table **500**.

At step S**106**, the CPU **321** sends the information of the tape group and Rkey to the tape library apparatus, and stores information such as the TG number, Rkey ID and the like on the tape to become the tape group.

FIG. **6** is a flowchart showing the processing to be performed during tape backup.

At step S**201**, the CPU **321** sends data and the Wkey to the tape library apparatus **350**. Here, the CPU **312** copies the Wkey ID and the Wkey ID of the configuration information table **500** as the Rkey and the Rkey ID.

At step S**202**, the controller **351** uses the Wkey stored in the memory **352** and controls the encoder/decoder unit **353** to encrypt the data.

At step S**203**, the transport mechanism unit **355** under the command of the CPU **321** transports the tape **356** storing the foregoing data to the tape drive **354**. The processing at step S**203** may be performed simultaneously with the processing at step S**202**, or the order of processing may be interchanged.

At step S**204**, the encrypted data is written onto the tape **356** with the tape drive **341**.

The restoration of data using the TG information restoration processing and the key information restoration processing, and the restoration of data using the key information restoration processing after performing tape import in the storage system **1** are now explained respectively.

Here, the contents stored in the key information file **223** and the TG information file **224** of the management terminal **200** are explained. FIG. **17** is a diagram showing the information stored in the key information file **223**. As shown in FIG. **17**, the key information file stores the Wkey ID, the Wkey ID, the Rkey and the Rkey ID. Further, FIG. **18** is a diagram showing the contents stored in the TG information file **224**. As shown in FIG. **18**, among the contents stored in the configuration information table **500**, the TG attribute (arbitrary information from the TG number column **510** to the encryption status column **519**) information, the Wkey ID, and the Rkey ID are stored. In other words, the TG information file does not store the Wkey and the Rkey. The key information file **223** and the configuration information file **224** are backup files of the configuration information table **500**

The restoration of data using the TG information restoration processing and the key information restoration processing is foremost explained.

FIG. **7** is a view showing a frame format briefly explaining the restoration of data using the TG information restoration processing and the key information restoration processing. FIG. **10** is a flowchart showing this restoration processing.

As shown in FIG. **7** and FIG. **10**, when the management terminal **200** receives a restoration command from the user (S**401**), it performs the TG information restoration (S**402**) and the key information restoration (S**403**) of the tape **356** to be restored according to the command. Here, the rewriting of key information of the configuration information table **500** is performed. If restoration cannot be performed, a message to such effect is displayed on a display device or the like (not shown) of the management terminal **200**, and notified to the user.

The storage apparatus **310** sends the TG information and the key information to the tape library apparatus **350** (S**404**).

The tape library apparatus **350** transports the tape **356** identified in the TG to the tape drive **354** (S**405**), and reads data from that tape **356** (S**406**). The controller **361** uses the key information to control the encoder/decoder unit **353**, and decrypts the encrypted data (S**407**). The decoded data is sent from the tape library apparatus **350** to the storage apparatus **310** (S**408**).

The storage apparatus **310** stores the decoded data in the LU corresponding to the TG (S**409**). The storage apparatus **310** reports the completion of data restoration to the management terminal **200** (S**410**).

The TG information restoration and the key information restoration in the data restoration using the TG information restoration processing and the key information restoration processing are explained below.

According to the transition diagram **600** described above, the status of the respective keys and key IDs during the creation of TG, after the key change, and after the key change backup will be (Wkey ID **1**, Wkey **1**, Rkey ID **1**, Rkey **1**) in the case of during the creation of TG, (Wkey ID **2**, Wkey **2**, Rkey ID **1**, Rkey **1**) in the case of after the key change, and (Wkey ID **2**, Wkey **2**, Rkey ID **2**, Rkey **2**) in the case of after the key change backup.

The statuses that can be adopted by the key ID stored in the TG information file **224** are (Wkey ID **1**, Rkey ID **1**) acquired with the key status being the K**1** status, (Wkey ID **2**, Rkey ID **1**) acquired with the key status being the K**2** status, and (Wkey ID **2**, Rkey ID **2**) acquired with the key status being the K**3** status.

FIG. **8** is a state diagram showing the status of keys and key IDs after the restoration of TG information based on the TG information restoration under the preconditions based on the transition diagram **600**.

As shown in FIG. **8**, the state diagram **700** includes a number column **710**, a TG information file content column **720**, and a configuration information after TG information restoration column **730**. The number column **710** shows the number. The TG information file content column **720** shows the specific contents of the TG information file. The configuration information after TG information restoration column **730** shows the contents of the configuration information after performing the TG information restoration.

Number "1" shows the TG information restoration processing that will use the TG information file acquired during the creation of the TG. Contents of the TG information file show TG number n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 1," and the Rkey ID is "Rkey ID 1." As a result of the TG information restoration being performed, the configuration information will show TG number; n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 1," the Rkey ID is "Rkey ID 1," the Wkey is "Invalid," and the Rkey is "Invalid."

Number "2" shows the TG information restoration processing that will use the TG information file acquired during the key change. Contents of the TG information file show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2," and the Rkey ID is "Rkey ID 1." As a result of the TG information restoration being performed, the configuration information will show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2," the Rkey ID is "Rkey ID," the Wkey is "Invalid," and the Rkey is "Invalid."

Number "3" shows the TG information restoration processing that will use the TG information file acquired during the tape backup after the key change. Contents of the TG information file show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2," and the Rkey ID is "Rkey ID 2." As a result of the TG information restoration being performed, the configuration information will show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2," the Rkey ID is "Rkey ID 2," the Wkey is "Invalid," and the Rkey is "Invalid."

FIG. **9** is a state diagram showing the state of the keys and key IDs restored in the key information restoration performed after the TG information restoration. The statuses of the keys and key IDs restored in the TG information restoration can additionally adopt three status based on the key information restoration. The nine statuses are respectively explained below. The specific processing contents of the key change restoration processing will be explained later with reference to FIG. **11**.

As shown in FIG. **9**, the state diagram **800** includes a number column **810**, a configuration information after TG information restoration column **820**, a key information file content column **830**, and a configuration information after key information restoration column **840**. The number column **810** shows the number. The configuration information after TG information restoration column **820** shows the same contents as the configuration information after TG information restoration column **730** illustrated in the state diagram of FIG. **8**. The key information file content column **830** shows the contents of the key information file after the key information restoration. The configuration information after key information restoration column **840** shows the configuration information after the key information restoration.

Numbers "1" to "3" show the configuration information after the TG information restoration of number "1" in FIG. **8**. The respective contents of numbers "1" to "3" are now explained. In the ensuing explanation, the Wkey ID **3** and the Wkey **3** are the key ID and key newly created during the key information restoration.

As the key information file of number "1" shown are TG number: n, Wkey ID; Wkey ID **1**, Wkey: Wkey **1**, Rkey ID; Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute, etc., Wkey ID: Wkey ID **1**, Wkey: Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**.

As the key information file of number "2" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. As the configuration after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **3**, Wkey: Wkey **3**, Rkey ID: Rkey ID **1**, AND Rkey: Rkey **1**.

As the key information file of number "3" shown are TG number: n, Wkey ID; Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**. Here, as the configuration information after key Information restoration, it is shown that the key information restoration is not possible.

Numbers "4" to "6" show the configuration information after TG information restoration of number "2" In FIG. **8**. The respective contents of numbers "4" to "6" are now explained.

As the key information file of number "4" shown are TG number: n, Wkey ID: Wkey ID **1**, Wkey; Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **3**, Wkey: Wkey **3**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**.

As the key information file of number "5" shown are TG number; n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**.

As the key information file of number "6" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**. Here, as the configuration information after key information restoration, it is shown that the key information restoration is not possible.

Numbers "7" to "9" show the configuration information after TG information restoration of number "3" in FIG. **8**. The respective contents of numbers "7" to "9" are now explained.

As the key information file of number "7" shown are TG number: n, Wkey ID: Wkey ID **1**, Wkey: Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. Here, as the configuration Information after key information restoration, it is shown that the key information restoration is not possible.

As the key information file of number "8" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**.

As the key information file of number "9" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **2**, Wkey; Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey; Rkey **2**.

The key information restoration processing is now explained. FIG. **11** is a flowchart showing the key information restoration processing.

At step **S301**, the CPU **210** compares the Rkey ID of the configuration information and the Wkey ID, Rkey ID of the key information file **223**. If they do not match, at step S**302**, the CPU **210** fails in the key restoration of that TG.

Meanwhile, if they match at step S**302**, the CPU **210** compares the Wkey ID of the configuration information and the Wkey ID of the key information file. If they match, at step S**304**, the CPU **210** copies the Wkey of the key information file **223** to the Wkey of the configuration information table **500**. If they do not match, at step S**305**, the CPU **210** newly creates a Wkey, and stores the Wkey ID and the Wkey in the configuration information table **500**.

At step S**306**, the CPU **210** copies the key that matched the Rkey ID of the configuration information to the Rkey of the configuration information using the Wkey ID or the Rkey ID of the key information file **223**. The key information restoration processing is thereby ended, and the Wkey ID, the Wkey, the Rkey ID, and the Rkey of the configuration information table **500** are restored.

The data restoration using the key information restoration processing after performing tape import is now explained.

FIG. **12** is a view showing a frame format briefly explaining the data restoration using the key information restoration processing after performing tape import. FIG. **15** is a flowchart showing this restoration processing.

As shown in FIG. **12** and FIG. **15**, for instance, the user imports the tape **356** by inserting the tape **356** from the VDL apparatus **400** into the tape drive **354** of the VDL apparatus **300**. The user operates the management terminal **200** to read the TG information of the tape **356** inserted into the tape drive **354**. When the management terminal **200** acquires a command for reading the TG information according to the user's operation (S**501**), it commands the storage apparatus **310** to read the TG information (S**502**).

When the storage apparatus **310** receives a read command from the management terminal **200**, it causes the tape library apparatus **350** to read the TG information from the tape **356** based on such command (S**504**).

After the tape library apparatus **350** reads the TG information from the tape **356**, it sends the TG information to the storage apparatus **310** (S**50S**). The storage apparatus **310** sends the TG information to the management terminal **200** (S**506**).

The management terminal **200** performs key information restoration based on the TG information sent from the storage apparatus **310** (S**507**). The key information restoration processing to be performed here is the same as the processing explained with reference to FIG. **11**.

Then, the storage apparatus **310** sends the TG information and the key information to the tape library apparatus **350** (S**508**).

The tape library apparatus **350** reads the data from the tape **356** (S**509**). The controller **351** uses the key information and controls the encoder/decoder unit **353** to decode the encrypted data (S**510**). The decoded data is then sent from the tape library apparatus **350** to the storage apparatus **310** (S**511**).

The storage apparatus **310** stores the decoded data in the LU corresponding to the TG (S**512**). The storage apparatus **310** thereafter reports the completion of data restoration to the management terminal **200** (S**513**).

The key information restoration in the data restoration using the key information restoration processing after performing tape import is now explained.

According to the transition diagram **600** described above, the status of the respective keys and key IDs during the creation of TG, after the key change, and after the key change backup will be (Wkey ID **1**, Wkey **1**, Rkey ID **1**, Rkey **1**) in the case of during the creation of TG, (Wkey ID **2**, Wkey **2**, Rkey ID **1**, Rkey **1**) in the case of after the key change, and (Wkey ID **2**, Wkey **2**, Rkey ID **2**, Rkey **2**) in the case of after the key change backup.

The statuses that can be adopted by the key ID stored in the TG information file **224** are (Wkey ID **1**, Rkey ID **1**) acquired with the key ID status being the T1 status, and (Wkey ID **2**, Rkey ID **2**) acquired with the key ID status being the T2 status.

FIG. **13** is a state diagram showing the status of keys and key IDs after the restoration of TG information based on the tape import under the preconditions based on the transition diagram **600**.

As shown in FIG. **13**, the state diagram **900** includes a number column **910**, a tape content management information content column **920**, and a configuration information after tape import column **930**. The number column **910** shows the number. The tape content management information content column **920** shows the management information being managed in the tape. The configuration information after tape import column **930** shows the configuration information after tape import.

Number "1" shows the processing to be performed when importing a tape that was backed up before the key change. Contents of the management information in the tape show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 1." As the configuration information after tape import shown are TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 1," the Wkey is "Invalid," the Rkey ID is "Rkey ID 1," and the Rkey is "Invalid."

Number "2" shows the processing to be performed when importing a tape that was backed up after the key change. Contents of the management information in the tape show TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2." As the configuration information after tape import shown are TG number: n, backup date and time, TG attribute, etc., and further show that the Wkey ID is "Wkey ID 2," the Wkey is "Invalid," the Rkey ID is "Rkey ID 2," and the Rkey is "Invalid."

FIG. **14** is a state diagram showing the state of the keys and key IDs restored in the key Information restoration performed after the TG information restoration. The statuses of the keys and key IDs restored in the TG information restoration can additionally adopt three status based on the key information restoration. The six statuses are respectively explained below. The specific processing contents of the key change restoration processing are the same as FIG. **11**, and the explanation thereof is omitted.

As shown in FIG. **14**, the state diagram **1000** includes a number column **1010**, a configuration information after tape import column **1030**, a key information file content column **1020**, and a configuration information after key information restoration column **1040**. The number column **1010** shows the number. The configuration information after tape import column **1020** shows the same contents as the configuration information after TG information restoration column **930** of the state diagram **900** illustrated in FIG. **13**. The key information file content column **1030** shows the contents of the key information file after key information restoration. The configuration information after key information restoration column **1040** shows the configuration information after the key information restoration.

Numbers "1" to "3" show the configuration information after tape import of number "1" in FIG. **13**. The respective contents of numbers "1" to "3" are now explained. In the ensuing explanation, the Wkey ID **3** and the Wkey **3** are the key ID and key newly created during the key information restoration.

As the key information file of number "1" shown are TG number: n, Wkey ID: Wkey ID **1**, Wkey: Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey; Rkey **1**. As the configuration information after tape import shown are TG number n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **1**, Wkey: Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**.

As the key information file of number "2" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID; Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **3**, Wkey: Wkey **3**, Rkey ID: Rkey ID **1**, and Rkey; Rkey **1**.

As the key information file of number "3" shown are TG number n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**. Here, as the configuration information after key information restoration, it is shown that the key information restoration is not possible.

Numbers "4" to "6" show the configuration information after tape import of number "2" in FIG. **13**. The respective contents of numbers "1" to "3" are now explained.

As the key information file of number "4" shown are TG number: n, Wkey ID; Wkey ID **1**, Wkey: Wkey **1**, Rkey ID: Rkey ID **1**, and Rkey: Rkey **1**. Here, as the configuration information after key information restoration, it is shown that the key information restoration is not possible.

As the key information file of number "5" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID; Rkey ID **1**, and Rkey: Rkey **1**. As the configuration information after key information restoration shown are TG number: n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**.

As the key information file of number "6" shown are TG number: n, Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**. As the configuration information after key information restoration shown are TG number; n, backup date and time, TG attribute etc., Wkey ID: Wkey ID **2**, Wkey: Wkey **2**, Rkey ID: Rkey ID **2**, and Rkey: Rkey **2**.

According to the present embodiment, the storage system **1** is able to restore the Rkey even when the Wkey and the Rkey are changed by using two types of keys; namely, the Wkey and Rkey, and backing up the key information file **223** and the TG information file **224** at a timing that these are newly created in both cases of restoring data stored in the tape of the VDL apparatus **300** or importing tape from another VDL apparatus **400** to the VDL apparatus **300** when the key for encrypting data has been changed. Thus, restoration of data from the tape can be conducted without the user having to perform key information restoration, and it is thereby possible to spare the user from the trouble of restoring key information.

The present invention can be broadly applied to a storage system, and its encryption key management method and encryption key management program.

What is claimed is:

1. A storage system, comprising:

a storage apparatus;

a tape library apparatus for backing up data stored in the storage apparatus; and

a management terminal for managing said storage apparatus and said tape library apparatus;

wherein said storage apparatus includes:

a key creation unit for creating a write key for encrypting data upon backing up data in a tape of said tape library apparatus, a write key ID of the write key, a read key for decrypting data that was encrypted with said write key, and a read key ID of the read key, and updating said write key and said write key ID without updating said read key and said read key ID; and

a management information file for associating management information concerning data with said created write key, write key ID, read key, and read key ID upon backing up said data in said storage apparatus to the tape in said tape library apparatus;

wherein said tape library apparatus includes:

a data processing unit for encrypting data using said write key ID upon writing data into said tape, and decrypting data of said tape using said read key ID upon reading data from said tape;

wherein said tape includes:

a tape management file containing at least said write key ID and said read key ID among said management information; and

wherein said management terminal includes:

a tape group information file for backing up information containing said write key ID and said read key ID stored in said management information file;

a key information file for backing up said write key, said write key ID, said read key and said read key ID stored in said management information file;

a key information processing unit for comparing said management information file with said key information file and, if said read key ID in said management information file matches said write key ID or said read key ID in said key information file, restoring said key information file to said management information file; and

a command unit for commanding restoration of a key of said tape based on said management information file restored by said key information processing unit, and

wherein the key information processing unit restores said key information file to said management information file by:

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file matches said write key ID in said key information file, creating an updated write key and an updated write key ID and storing said updated write key and said updated write key ID in said management information file as said write key and said write key ID in said management information file,

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file does not match said write key ID in said key information file, copying said write key in said key information file to said management information file as said write key in said management information file,

if said write key ID in said management information file matches said read key ID in said management information file, copying said write key in said key information file to said management information file as said read key in said management information file, and

if said read key ID in said key information file matches said read key ID in said management information file, copying said read key in said key information file to said management information file as said read key in said management information file.

2. The storage system according to claim **1**, wherein said key creation unit creates a new write key, a write key ID, a read key and a read key ID upon receiving a setup command from said management terminal for backing up data in said tape; and

wherein said management terminal backs up said key information file upon receiving said setup command, upon changing the key to said new write key, write key ID, read key and read key ID, and upon backing up data in said tape after changing said key.

3. The storage system according to claim **2**, wherein the designation of the tape in said tape library apparatus to be restored is based on a command from said management terminal.

4. The storage system according to claim **2**, wherein said storage system includes a second tape library apparatus that is different from said tape library apparatus; and

wherein, upon importing a tape in said tape library apparatus to said different second tape library apparatus, said management terminal restores the data stored in the imported tape.

5. The storage system according to claim **1**, wherein said storage apparatus includes a random number generation unit; and

wherein said key creation unit creates said write key using a random number generated with said random number generation unit.

6. The storage system according to claim **5**, further comprising:

an apparatus-specific information storage unit for storing apparatus-specific information which is information that is unique to the storage apparatus; and

wherein said write key and said read key are encrypted with said apparatus-specific information upon being stored in said management information file, and said write key and said read key are decrypted with said apparatus-specific information upon being read from said management information file.

7. The storage system according to claim **6**, wherein said apparatus-specific information is a serial number.

8. The storage system according to claim **2**, wherein said write key and said read key, and said write key ID and said read key ID are respectively equivalent.

9. The storage system according to claim **2**, wherein said write key ID is a unique ID in said storage system.

10. The storage system according to claim **1**, wherein management information concerning said data includes tape group information corresponding to a logical unit for backing up data in said storage apparatus.

11. An encryption key management method of a storage system comprising a storage apparatus; a tape library apparatus for backing up data stored in the storage apparatus; and a management terminal for managing said storage apparatus and said tape library apparatus;

wherein said storage apparatus includes:

a key creation unit for creating a write key for encrypting data upon backing up data in a tape of said tape library apparatus, a write key ID of the write key, a read key for decrypting data that was encrypted with said write key, and a read key ID of the read key, and updating said write key and said write key ID without updating said read key and said read key ID; and

a management information file for associating management information concerning data with said created write key, write key ID, read key, and read key ID upon backing up said data in said storage apparatus to the tape in said tape library apparatus;

wherein said tape library apparatus includes:

a data processing unit for encrypting data using said write key ID upon writing data into said tape, and decrypting data of said tape using said read key ID upon reading data from said tape;

wherein said tape includes:

a tape management file containing at least said write ID and said read key ID among said management information

wherein said management terminal includes:

a tape group information file for backing up information containing said write key ID and said read key ID stored in said management information file;

a key information file for backing up said write key, said write key ID, said read key and said read key ID stored in said management information file; and

wherein said encryption key management method comprises:

comparing said management information file with said key information file; and

if said read key ID in said management information file matches said write key ID or said read key ID in said key information file, restoring said key information file to said management information file by:

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file matches said write key ID in said key information file, creating an updated write key and an updated write key ID and storing said updated write key and said updated write key ID in said management information file as said write key and said write key ID in said management information file;

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file does not match said write key ID in said key information file, copying said write key in said key information file to said management information file as said write key in said management information file;

if said write key ID in said management information file matches said read key ID in said management information file, copying said write key in said key information file to said management information file as said read key in said management information file;

if said read key ID in said key information file matches said read key ID in said management information file, copying said read key in said key information file to said management information file as said read key in said management information file; and

commanding restoration of a key of said tape based on said management information file restored with said key information processing unit.

12. The encryption key management method of a storage system according to claim **11**, wherein said key creation unit a new write key, a write key ID, a second key and a second key ID upon receiving a setup command from said management terminal for backing up data in said tape; and

Wherein said management terminal backs up said key information file upon receiving said setup command, upon changing the key to said new write key, write key ID, second key and second key ID, and upon backing up data in said tape after changing said key.

13. A non-transitory computer-usable medium having computer readable instructions stored thereon for execution by a processor of a management terminal for managing a storage apparatus and a tape library apparatus for backing up data stored in the storage apparatus in a storage system to perform an encryption key management method of the storage system;

wherein said storage apparatus includes:

a key creation unit for creating a write key for encrypting data upon backing up data in a tape of said tape library apparatus, a write key ID of the write key, a read key for decrypting data that was encrypted with said write key, and a read key ID of the read key, and updating said write key and said write key ID without updating said read key and said read key ID; and

a management information file for associating management information concerning data with said created write key, write key ID, read key, and read key ID upon backing up said data in said storage apparatus to the tape in said tape library apparatus;

wherein said tape library apparatus includes:

a data processing unit for encrypting data using said write key ID upon writing data into said tape, and decrypting data of said tape using said read key ID upon reading data from said tape;

wherein said tape includes:

a tape management file containing at least said write key ID and said read key ID among said management information;

wherein said management terminal includes:

a tape group information file for backing up information containing said write key ID and said read key ID stored in said management information file; and

a key information file for backing up said write key, said write key ID, said read key and said read key ID stored in said management information file;

said encryption key management method comprising:

comparing said management information file with said key information file;

if said read key ID in said management information file matches said write key ID or said read key ID in said key information file, restoring said key information file to said management information file by:

if said second key ID in said management information file matches both said first key ID and said second key ID in said key information file and said first key ID in said management information file matches said first key ID in said key information file, creating an updated first key and an updated first key ID and storing said updated first key and said updated first key ID in said management information file, and

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file matches said write key ID in said key information file, creating an updated write key and an updated write key ID and storing said updated write key and said updated write key ID in said management information file as said write key and said write key ID in said management information file,

if said read key ID in said management information file matches both said write key ID and said read key ID in said key information file and said write key ID in said management information file does not match said write key ID in said key information file, copying said write key in said key information file to said management information file as said write key in said management information file,

if said write key ID in said management information file matches said read key ID in said management information file, copying said write key in said key information file to said management information file as said read key in said management information file, and

if said read key ID in said key information file matches said read key ID in said management information file, copying said read key in said key information file to said management information file as said read key in said management information file; and

commanding restoration of a key of said tape based on said management information file restored with said key information processing unit.

14. The computer-usable medium according to claim **13**, wherein said key creation unit creates a new write key, a write key ID, a read key and a read key ID upon receiving a setup command from said management terminal for backing up data in said tape; and

wherein said encryption key management program causes said management terminal to function as means for backing up said key information file upon receiving said setup command, upon changing the key to said new write key, write key ID, read key and read key ID, and upon backing up data in said tape after changing said key.

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