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(12) **Reissued Patent**

Hattori et al.

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(54) **DATA SEARCH DEVICE, DATA SEARCH METHOD, COMPUTER READABLE MEDIUM STORING DATA SEARCH PROGRAM, DATA REGISTRATION DEVICE, DATA REGISTRATION METHOD, COMPUTER READABLE MEDIUM STORING DATA REGISTRATION PROGRAM, AND INFORMATION PROCESSING DEVICE**

(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**, Chiyoda-ku (JP)

(72) Inventors: **Mitsuhiro Hattori**, Tokyo (JP); **Nori Matsuda**, Tokyo (JP); **Takashi Ito**, Tokyo (JP); **Takumi Mori**, Tokyo (JP); **Takato Hirano**, Tokyo (JP)

(73) Assignee: **MITSUBISHI ELECTRIC CORPORATION**, Chiyoda-ku (JP)

(21) Appl. No.: **15/984,468**

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Related U.S. Patent Documents

Reissue of:

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Issued: **Jul. 12, 2016**
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PCT Filed: **Jan. 25, 2012**
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§ 371 (c)(1),
(2) Date: **Apr. 10, 2014**
PCT Pub. No.: **WO2013/111284**
PCT Pub. Date: **Aug. 1, 2013**

(51) **Int. Cl.**

H04L 29/06	(2006.01)
H04L 9/30	(2006.01)
H04L 9/08	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 9/0894*** (2013.01); ***H04L 9/30*** (2013.01); ***H04L 9/3073*** (2013.01); ***H04L 63/065*** (2013.01); *H04L 2209/42* (2013.01)

(58) **Field of Classification Search**

CPC H04L 9/0894; H04L 9/30; H04L 9/3073; H04L 2209/42; H04L 63/065

See application file for complete search history.

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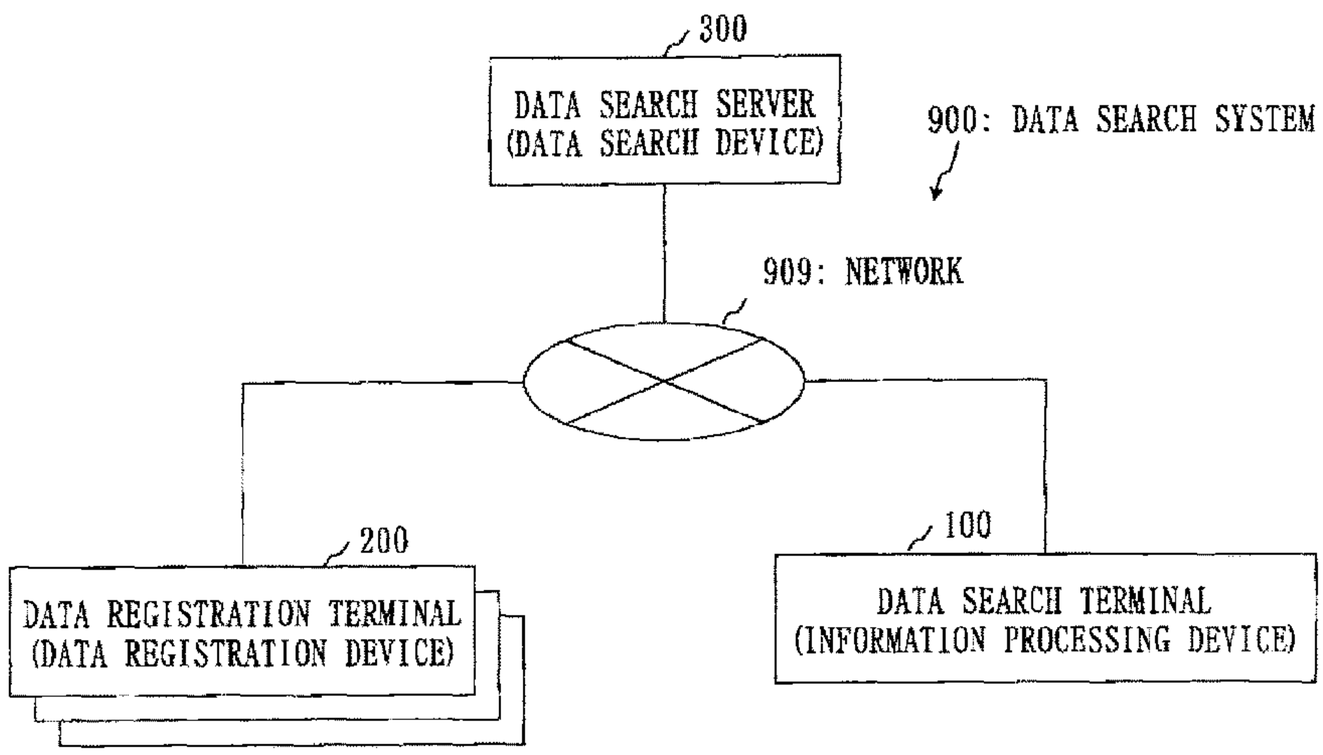
Primary Examiner — William H. Wood

(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A data search server stores a system ciphertext including a data ciphertext and a keyword ciphertext in each category-specific DB unit for each data category, and stores each category-determination secret key being associated with each category-specific DB unit. A search request receiving unit receives from a data search terminal a search request including a search trapdoor and an index tag. A data searching unit searches for a category-determination secret key with which the index tag is decrypted to the same value as a key-determination value. Using the search trapdoor, the data searching unit performs a search of a Public-key Encryption with Keyword Search scheme on system ciphertexts in a category-specific DB unit associated with this category-determination secret key. A search result transmit-

(Continued)



ting unit transmits to the data search terminal a data ciphertext included in a system ciphertext which has been found as a hit in the search.

21 Claims, 27 Drawing Sheets

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WO	WO 2011/086668	A1	7/2011
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Fig.1

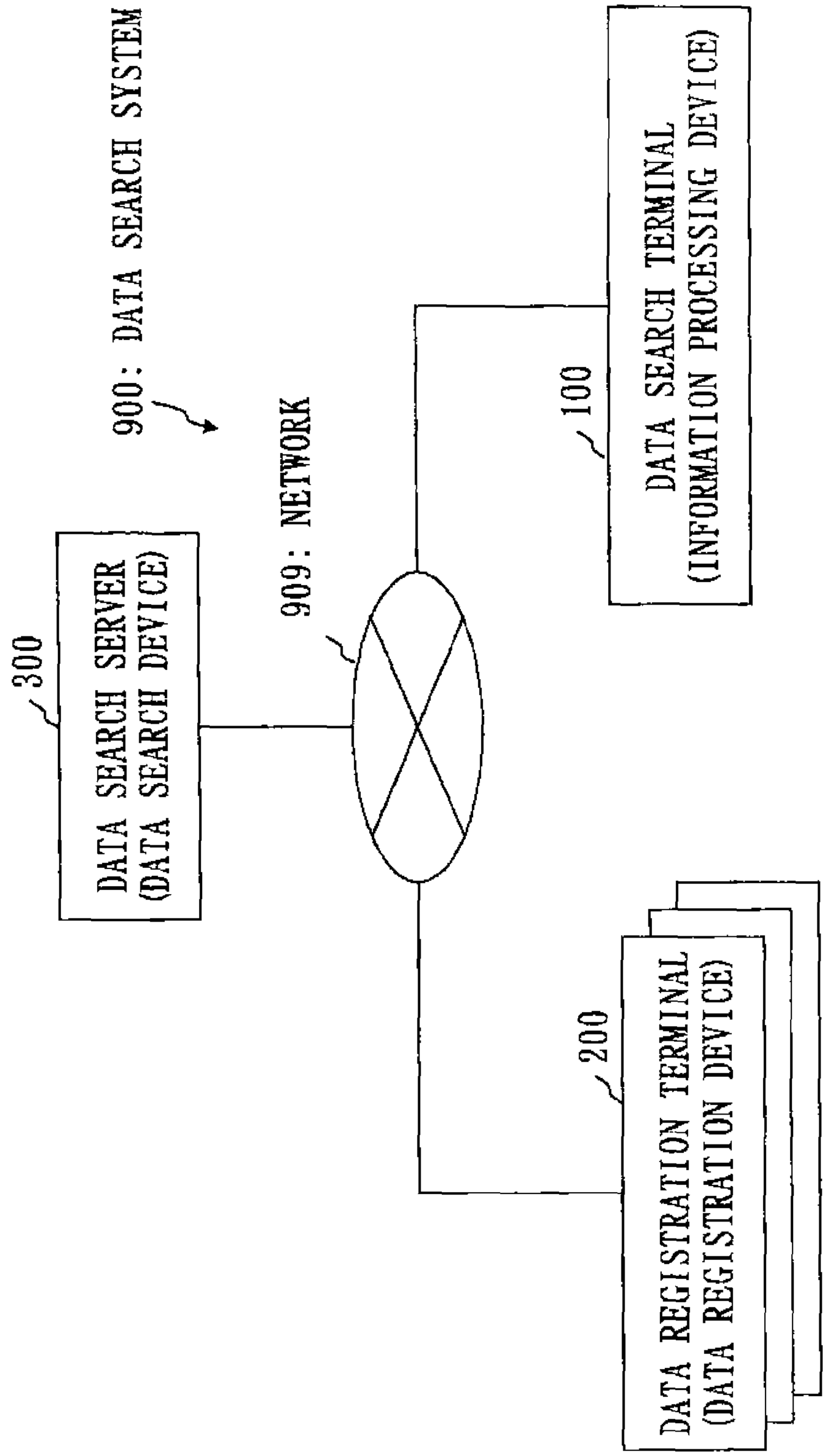

900: DATA SEARCH SYSTEM
300
DATA SEARCH SERVER
(DATA SEARCH DEVICE)
909: NETWORK
100
DATA SEARCH TERMINAL
(INFORMATION PROCESSING DEVICE)
200
DATA REGISTRATION TERMINAL
(DATA REGISTRATION DEVICE)

Fig. 2

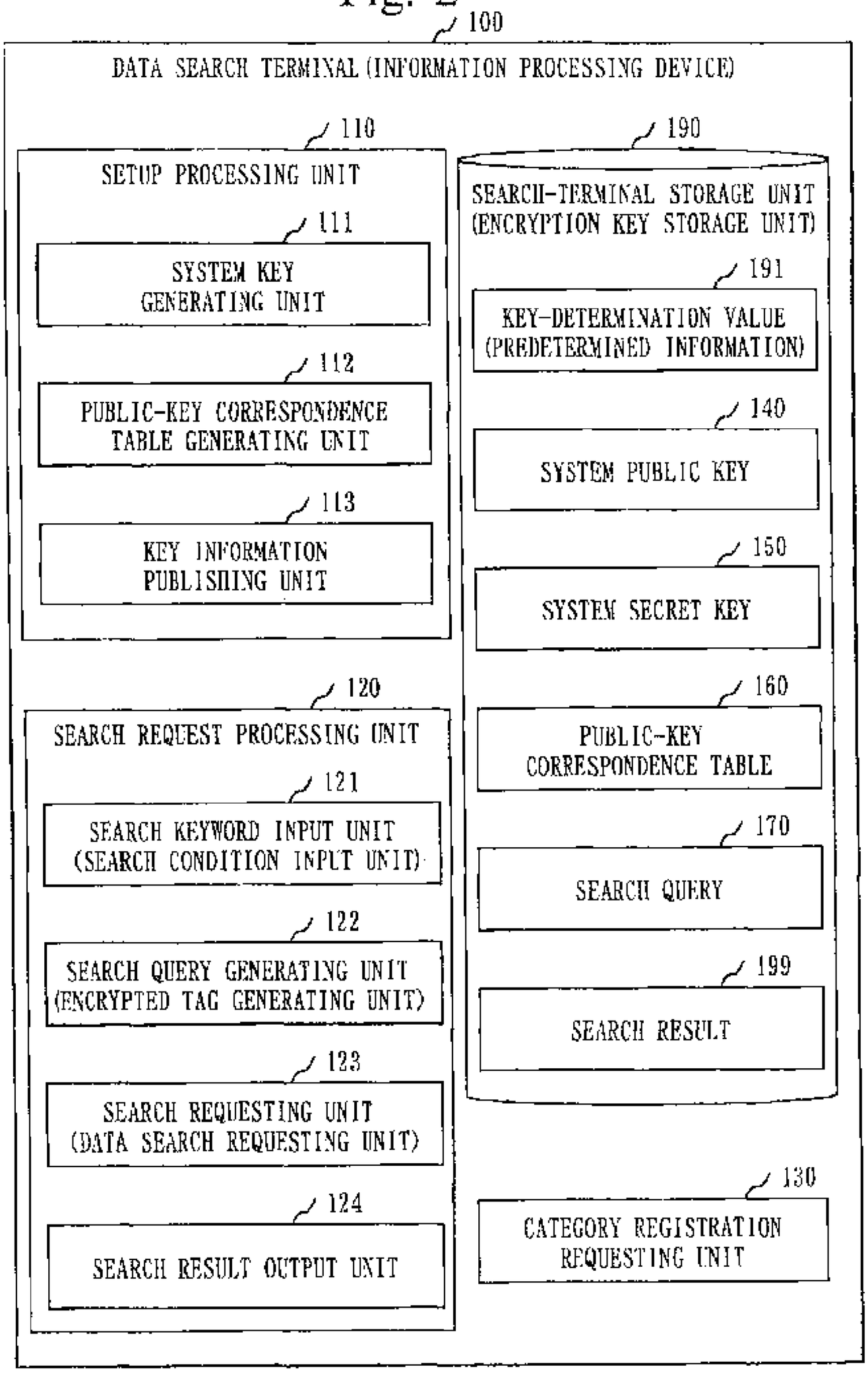

100
DATA SEARCH TERMINAL (INFORMATION PROCESSING DEVICE)
110
SETUP PROCESSING UNIT
111
SYSTEM KEY GENERATING UNIT
112
PUBLIC-KEY CORRESPONDENCE TABLE GENERATING UNIT
113
KEY INFORMATION PUBLISHING UNIT
120
SEARCH REQUEST PROCESSING UNIT
121
SEARCH KEYWORD INPUT UNIT (SEARCH CONDITION INPUT UNIT)
122
SEARCH QUERY GENERATING UNIT (ENCRYPTED TAG GENERATING UNIT)
123
SEARCH REQUESTING UNIT (DATA SEARCH REQUESTING UNIT)
124
SEARCH RESULT OUTPUT UNIT
190
SEARCH-TERMINAL STORAGE UNIT (ENCRYPTION KEY STORAGE UNIT)
191
KEY-DETERMINATION VALUE (PREDETERMINED INFORMATION)
140
SYSTEM PUBLIC KEY
150
SYSTEM SECRET KEY
160
PUBLIC-KEY CORRESPONDENCE TABLE
170
SEARCH QUERY
199
SEARCH RESULT
130
CATEGORY REGISTRATION REQUESTING UNIT

Fig. 3

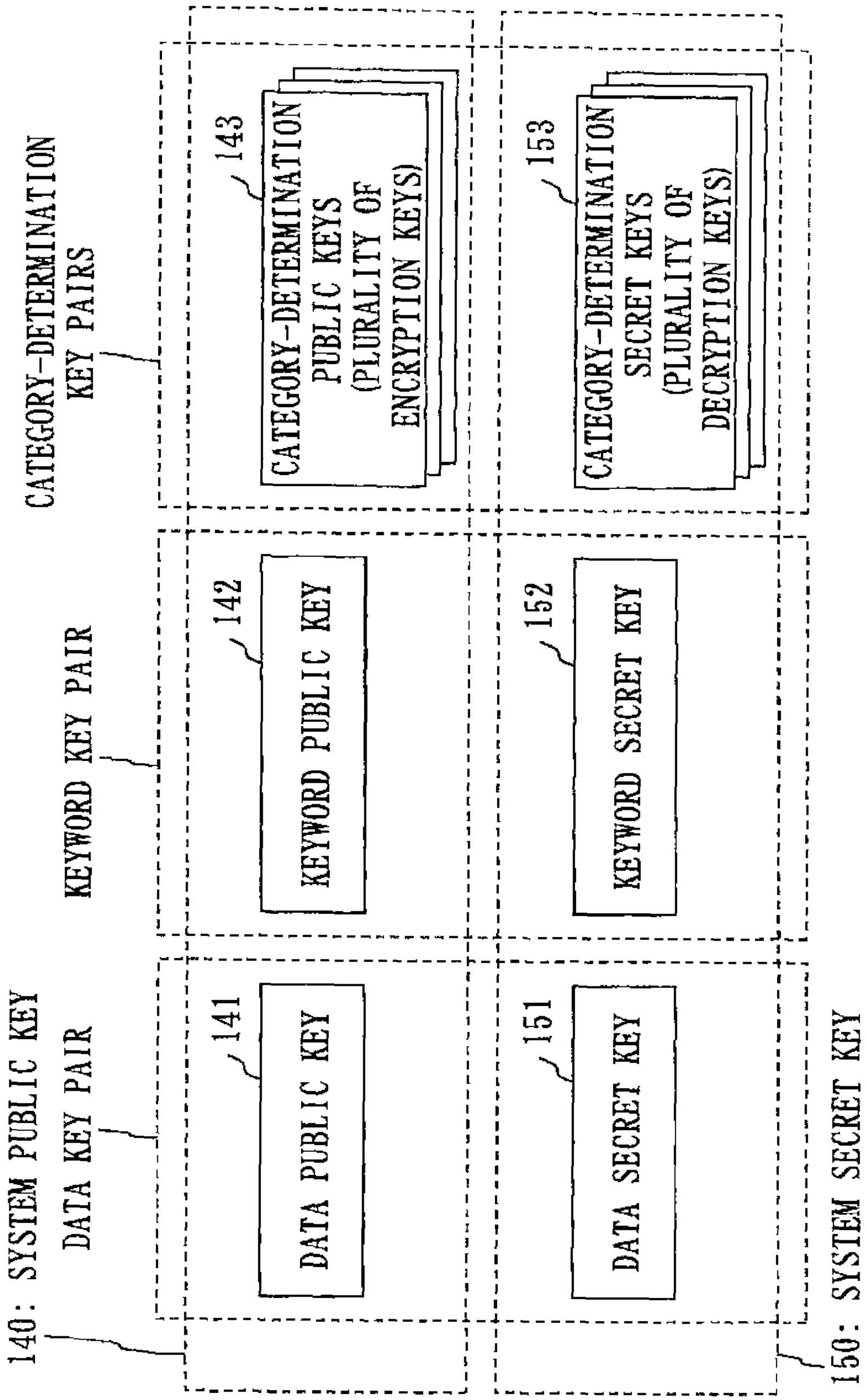

140: SYSTEM PUBLIC KEY
DATA KEY PAIR
141
DATA PUBLIC KEY
142
KEYWORD PUBLIC KEY
143
CATEGORY-DETERMINATION PUBLIC KEYS (PLURALITY OF ENCRYPTION KEYS)
KEYWORD KEY PAIR
CATEGORY-DETERMINATION KEY PAIRS
150: SYSTEM SECRET KEY
151
DATA SECRET KEY
152
KEYWORD SECRET KEY
153
CATEGORY-DETERMINATION SECRET KEYS (PLURALITY OF DECRYPTION KEYS)

Fig. 4

160: PUBLIC-KEY CORRESPONDENCE TABLE

CATEGORY-DETERMINATION PUBLIC KEY	CATEGORY
PK_1	PATENT
PK_2	DESIGN
...	...

Fig. 5

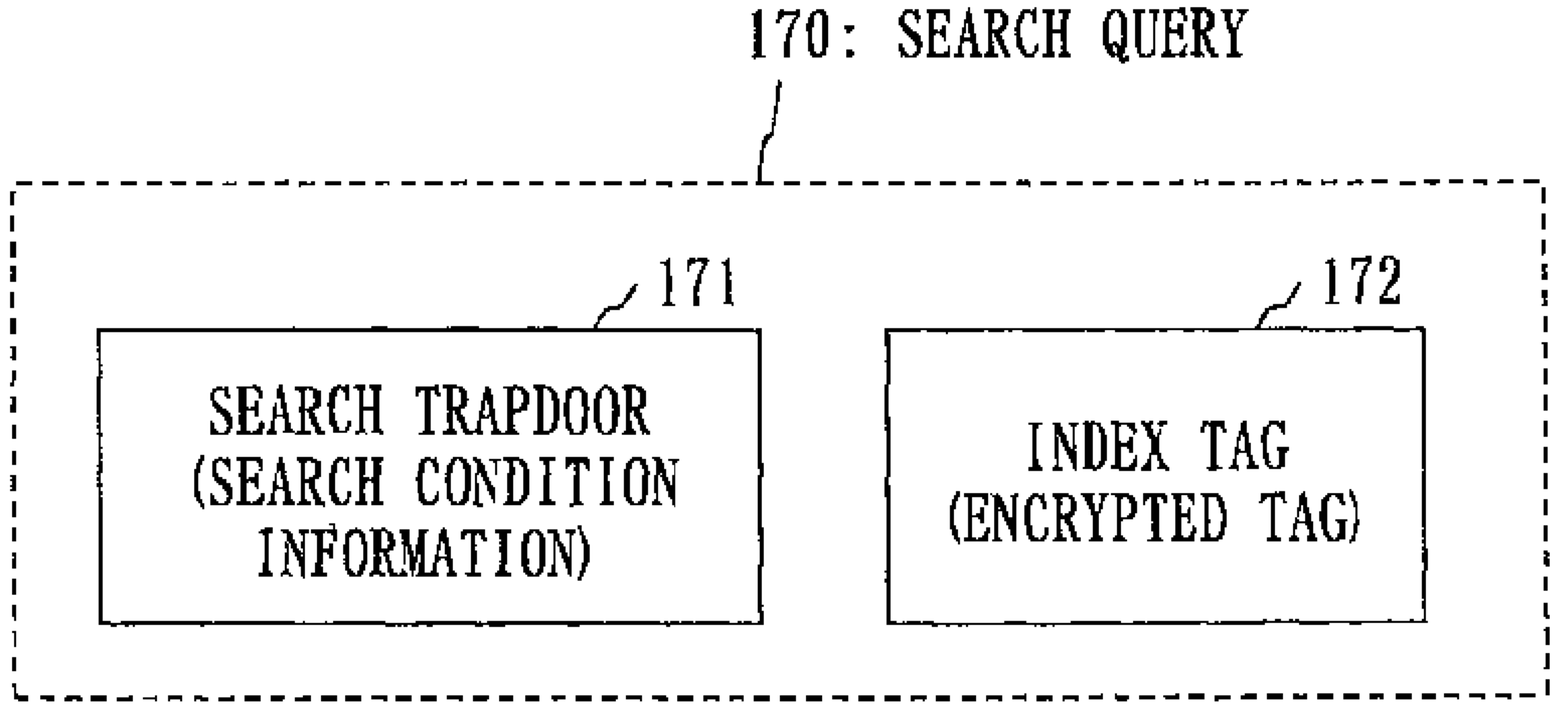


Fig. 6

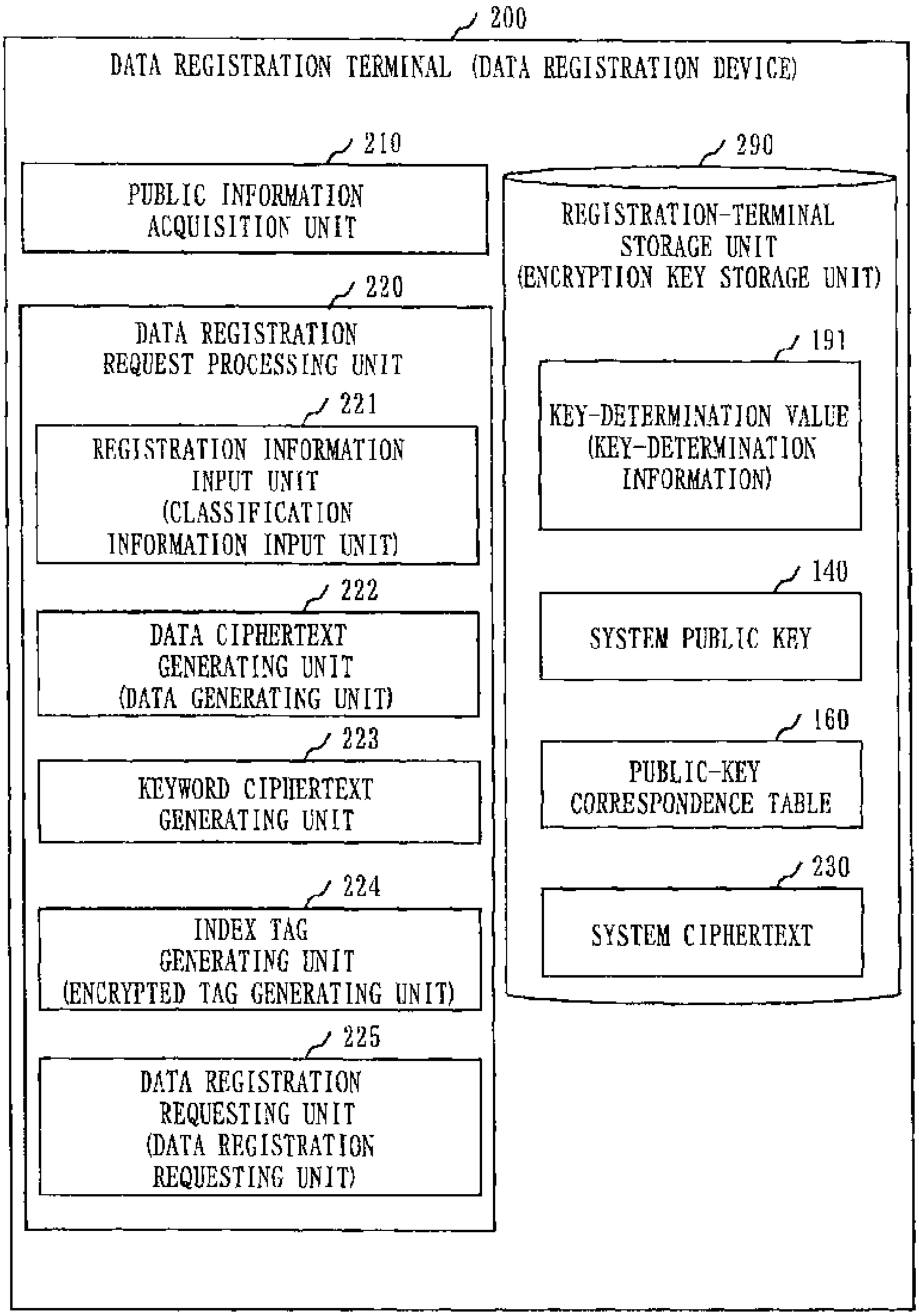

200
DATA REGISTRATION TERMINAL (DATA REGISTRATION DEVICE)
210
PUBLIC INFORMATION ACQUISITION UNIT
220
DATA REGISTRATION REQUEST PROCESSING UNIT
221
REGISTRATION INFORMATION INPUT UNIT (CLASSIFICATION INFORMATION INPUT UNIT)
222
DATA CIPHERTEXT GENERATING UNIT (DATA GENERATING UNIT)
223
KEYWORD CIPHERTEXT GENERATING UNIT
224
INDEX TAG GENERATING UNIT (ENCRYPTED) TAG GENERATING UNIT)
225
DATA REGISTRATION REQUESTING UNIT (DATA REGISTRATION REQUESTING UNIT)
290
REGISTRATION-TERMINAL STORAGE UNIT (ENCRYPTION KEY STORAGE UNIT)
191
KEY-DETERMINATION VALUE (KEY-DETERMINATION INFORMATION)
140
SYSTEM PUBLIC KEY
160
PUBLIC-KEY CORRESPONDENCE TABLE
230
SYSTEM CIPHERTEXT

Fig.7

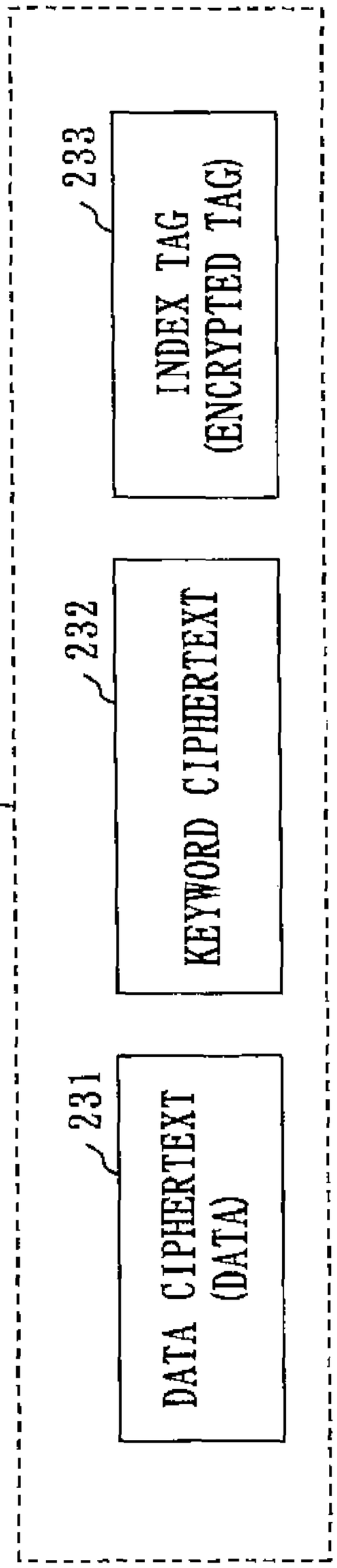

230: SYSTEM CIPHERTEXT
233
INDEX TAG
(ENCRYPTED TAG)
232
KEYWORD CIPHERTEXT
231
DATA CIPHERTEXT
(DATA)

Fig. 8

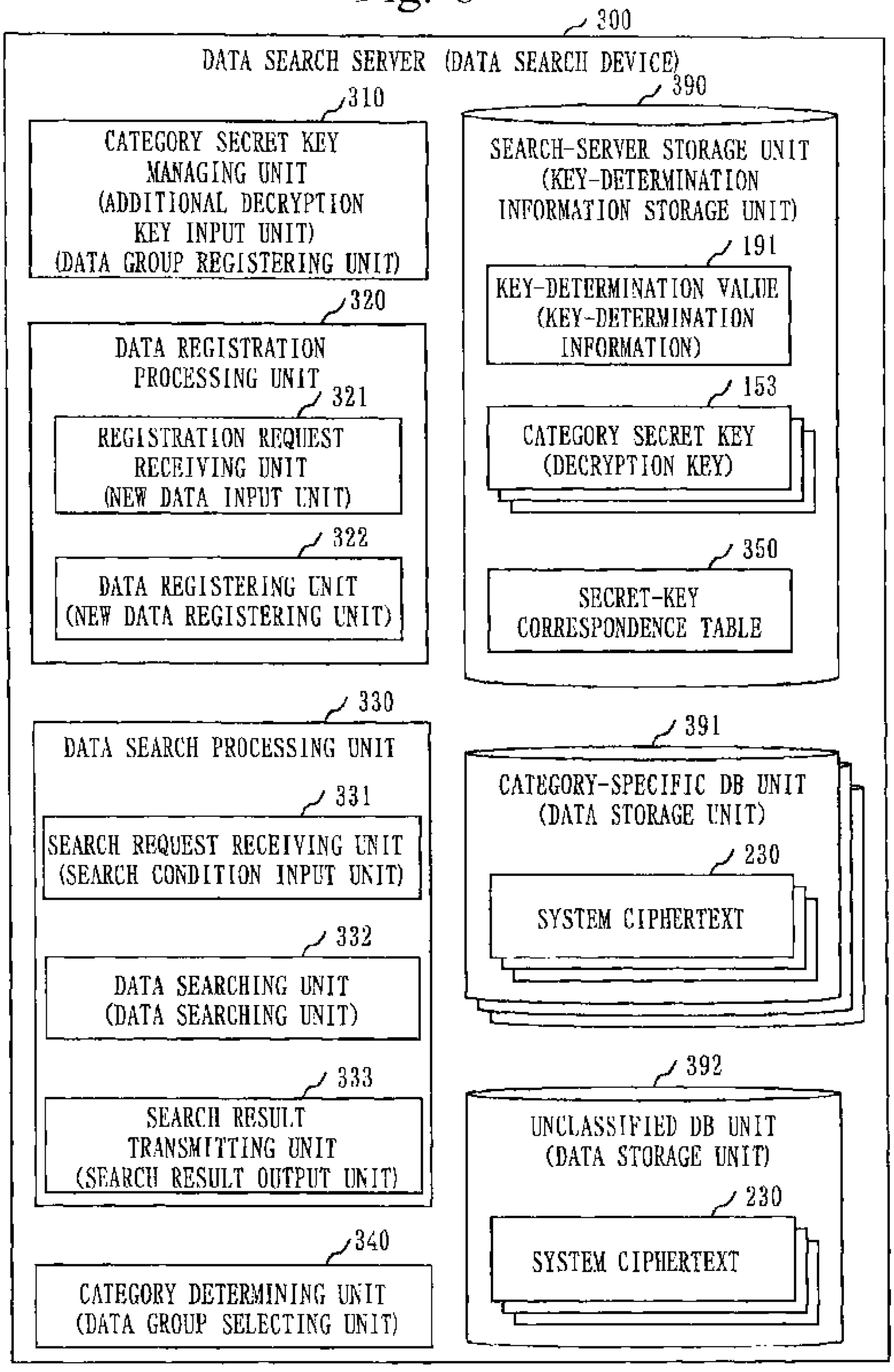

300
DATA SEARCH SERVER (DATA SEARCH DEVICE)
310
CATEGORY SECRET KEY MANAGING UNIT (ADDITIONAL DECRYPTION KEY INPUT UNIT) (DATA GROUP REGISTERING UNIT)
320
DATA REGISTRATION PROCESSING UNIT
321
REGISTRATION REQUEST RECEIVING UNIT (NEW DATA INPUT UNIT)
322
DATA REGISTERING UNIT (NEW DATA REGISTERING UNIT)
330
DATA SEARCH PROCESSING UNIT
331
SEARCH REQUEST RECEIVING UNIT (SEARCH CONDITION INPUT UNIT)
332
DATA SEARCHING UNIT (DATA SEARCHING UNIT)
333
SEARCH RESULT TRANSMITTING UNIT (SEARCH RESULT OUTPUT UNIT)
340
CATEGORY DETERMINING UNIT (DATA GROUP SELECTING UNIT)
390
SEARCH-SERVER STORAGE UNIT (KEY-DETERMINATION INFORMATION STORAGE UNIT)
191
KEY-DETERMINATION VALUE (KEY-DETERMINATION INFORMATION)
153
CATEGORY SECRET KEY (DECRYPTION KEY)
350
SECRET-KEY CORRESPONDENCE TABLE
391
CATEGORY-SPECIFIC DB UNIT (DATA STORAGE UNIT)
230
SYSTEM CIPHERTEXT
392
UNCLASSIFIED DB UNIT (DATA STORAGE UNIT)
230
SYSTEM CIPHERTEXT

Fig. 9

350: SECRET-KEY CORRESPONDENCE TABLE

CATEGORY-DETERMINATION SECRET KEY	CATEGORY-SPECIFIC DB UNIT
SK_1	DB_1
SK_2	DB_2
...	...

Fig. 10

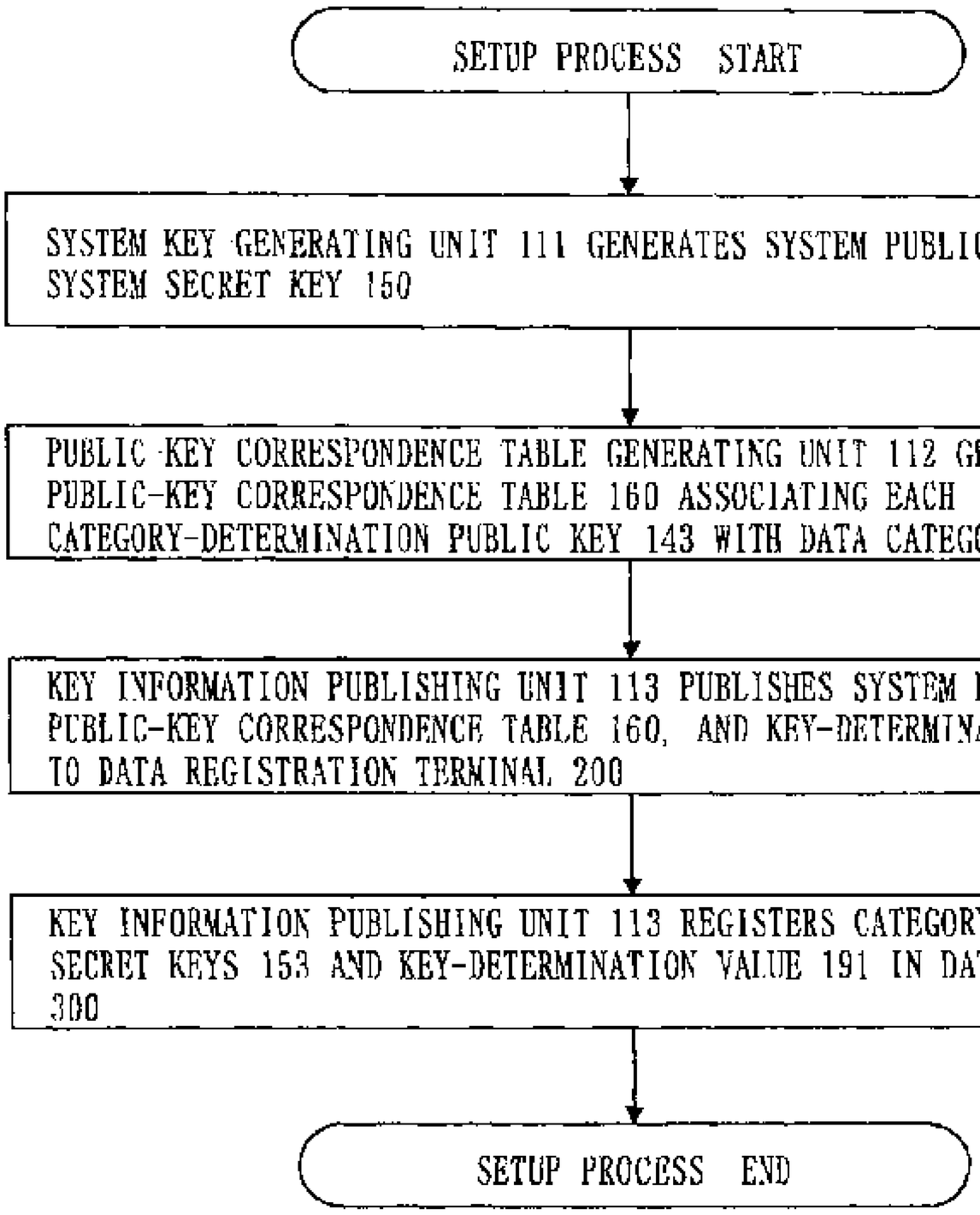

SETUP PROCESS START
S110
SYSTEM KEY GENERATING UNIT 111 GENERATES SYSTEM PUBLIC KEY 140 AND SYSTEM SECRET KEY 150
S120
PUBLIC KEY CORRESPONDENCE TABLE GENERATING UNIT 112 GENERATES PUBLIC-KEY CORRESPONDENCE TABLE 160 ASSOCIATING EACH CATEGORY-DETERMINATION PUBLIC KEY 143 WITH DATA CATEGORY
S130
KEY INFORMATION PUBLISHING UNIT 113 PUBLISHES SYSTEM PUBLIC KEY 140, PUBLIC-KEY CORRESPONDENCE TABLE 160, AND KEY-DETERMINATION VALUE 191 TO DATA REGISTRATION TERMINAL 200
S131
KEY INFORMATION PUBLISHING UNIT 113 REGISTERS CATEGORY-DETERMINATION SECRET KEYS 153 AND KEY-DETERMINATION VALUE 191 IN DATA SEARCH SERVER 300
SETUP PROCESS END

Fig. 11

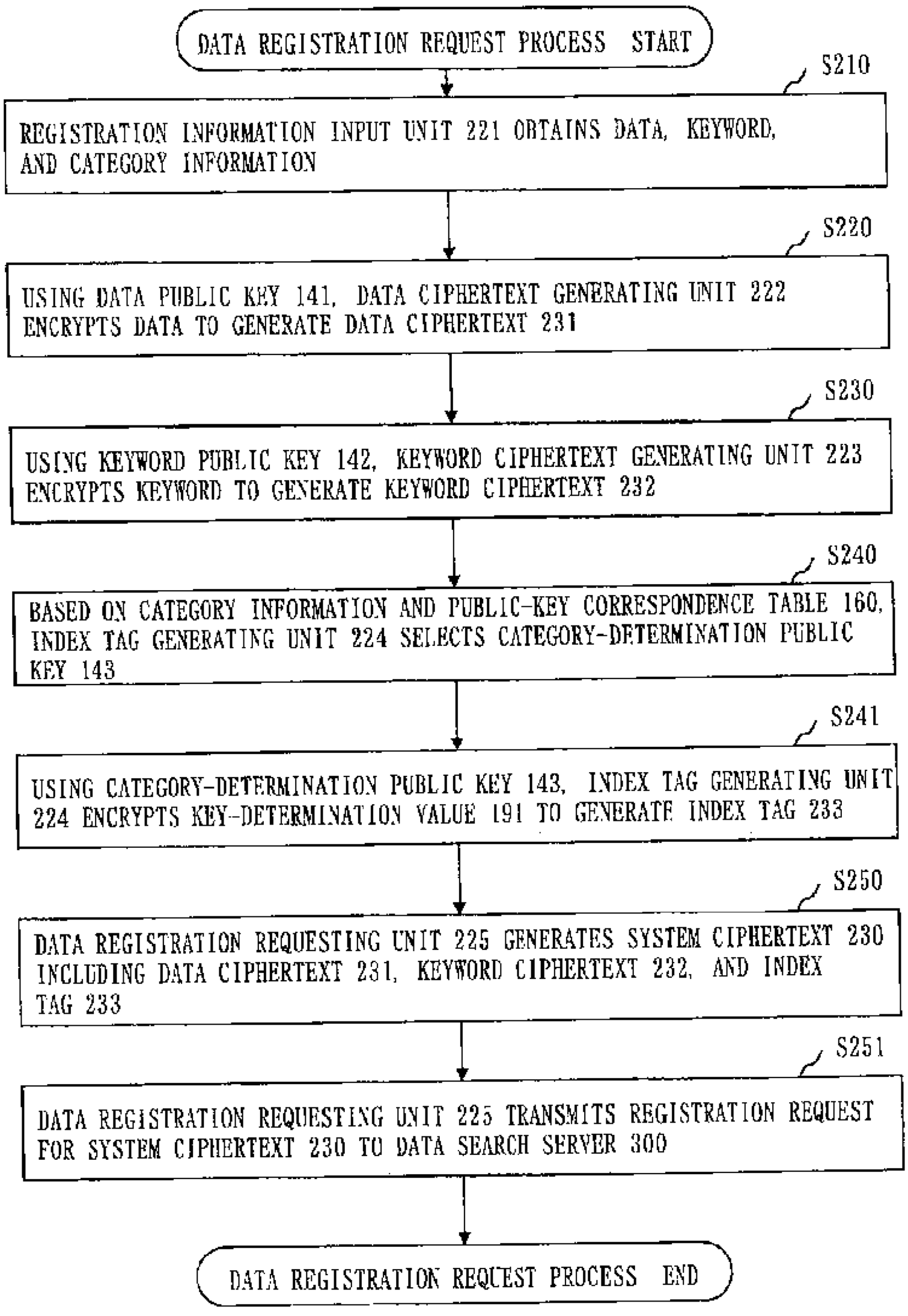

DATA REGISTRATION REQUEST PROCESS START
S210
REGISTRATION INFORMATION INPUT UNIT 221 OBTAINS DATA, KEYWORD, AND CATEGORY INFORMATION
S220
USING DATA PUBLIC KEY 141, DATA CIPHERTEXT GENERATING UNIT 222 ENCRYPTS DATA TO GENERATE DATA CIPHERTEXT 231
S230
USING KEYWORD PUBLIC KEY 142, KEYWORD CIPHERTEXT GENERATING UNIT 223 ENCRYPTS KEYWORD TO GENERATE KEYWORD CIPHERTEXT 232
S240
BASED ON CATEGORY INFORMATION AND PUBLIC-KEY CORRESPONDENCE TABLE 160, INDEX TAG GENERATING UNIT 224 SELECTS CATEGORY-DETERMINATION PUBLIC KEY 143
S241
USING CATEGORY-DETERMINATION PUBLIC KEY 143, INDEX TAG GENERATING UNIT 224 ENCRYPTS KEY-DETERMINATION VALUE 191 TO GENERATE INDEX TAG 233
S250
DATA REGISTRATION REQUESTING UNIT 225 GENERATES SYSTEM CIPHERTEXT 230 INCLUDING DATA CIPHERTEXT 231, KEYWORD CIPHERTEXT 232, AND INDEX TAG 233
S251
DATA REGISTRATION REQUESTING UNIT 225 TRANSMITS REGISTRATION REQUEST FOR SYSTEM CIPHERTEXT 230 TO DATA SEARCH SERVER 300
DATA REGISTRATION REQUEST PROCESS END

Fig. 12

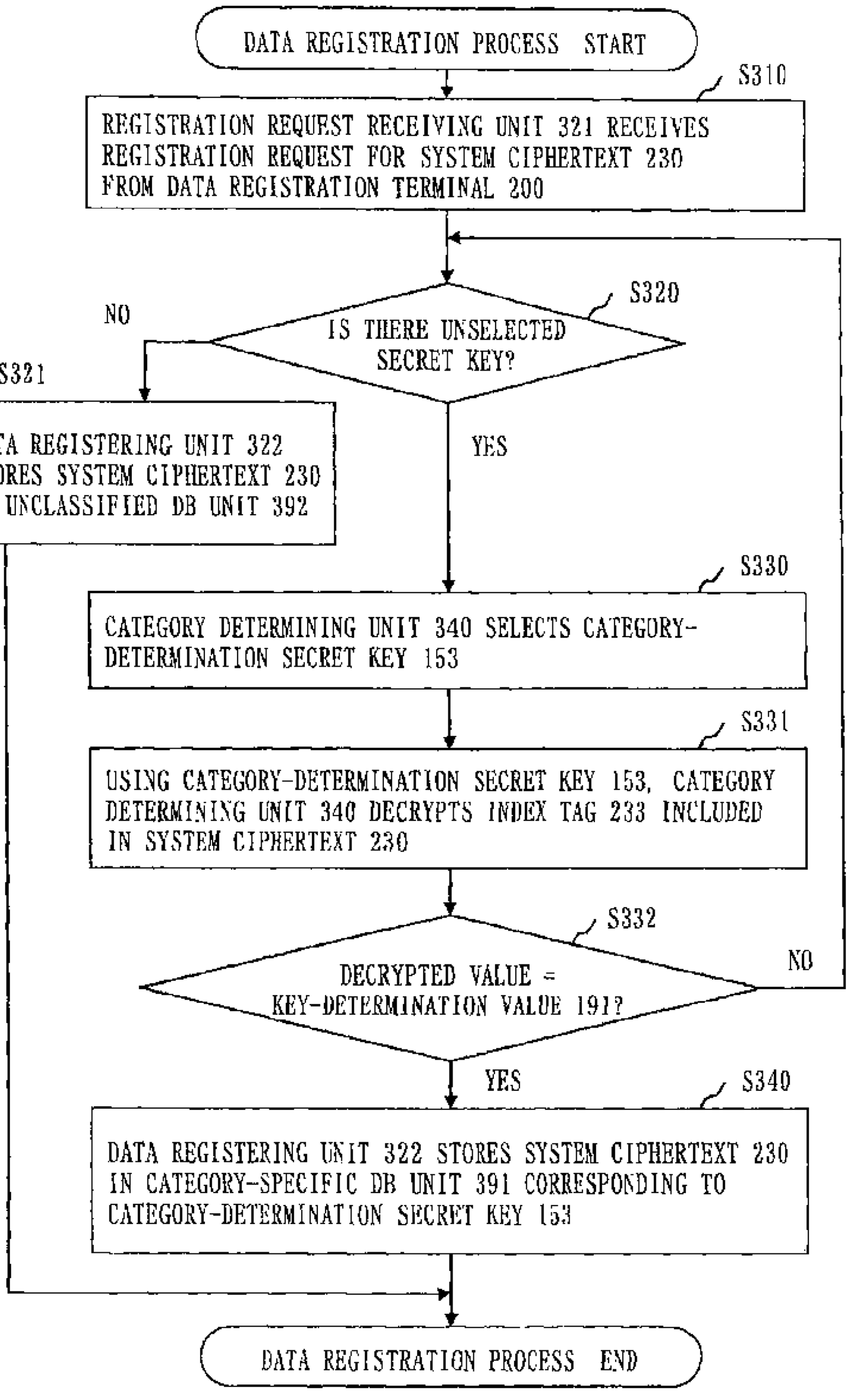

DATA REGISTRATION PROCESS START
S310
REGISTRATION REQUEST RECEIVING UNIT 321 RECEIVES REGISTRATION REQUEST FOR SYSTEM CIPHERTEXT 230 FROM DATA REGISTRATION TERMINAL 200
S320
IS THERE UNSELECTED SECRET KEY?
NO
S321
DATA REGISTERING UNIT 322 STORES SYSTEM CIPHERTEXT 230 IN UNCLASSIFIED DB UNIT 392
YES
S330
CATEGORY DETERMINING UNIT 340 SELECTS CATEGORY-DETERMINATION SECRET KEY 153
S331
USING CATEGORY-DETERMINATION SECRET KEY 153, CATEGORY DETERMINING UNIT 340 DECRYPTS INDEX TAG 233 INCLUDED IN SYSTEM CIPHERTEXT 230
S332
DECRYPTED VALUE = KEY-DETERMINATION VALUE 191?
NO
YES
S340
DATA REGISTERING UNIT 322 STORES SYSTEM CIPHERTEXT 230 IN CATEGORY-SPECIFIC DB UNIT 391 CORRESPONDING TO CATEGORY-DETERMINATION SECRET KEY 153
DATA REGISTRATION PROCESS END

Fig. 13

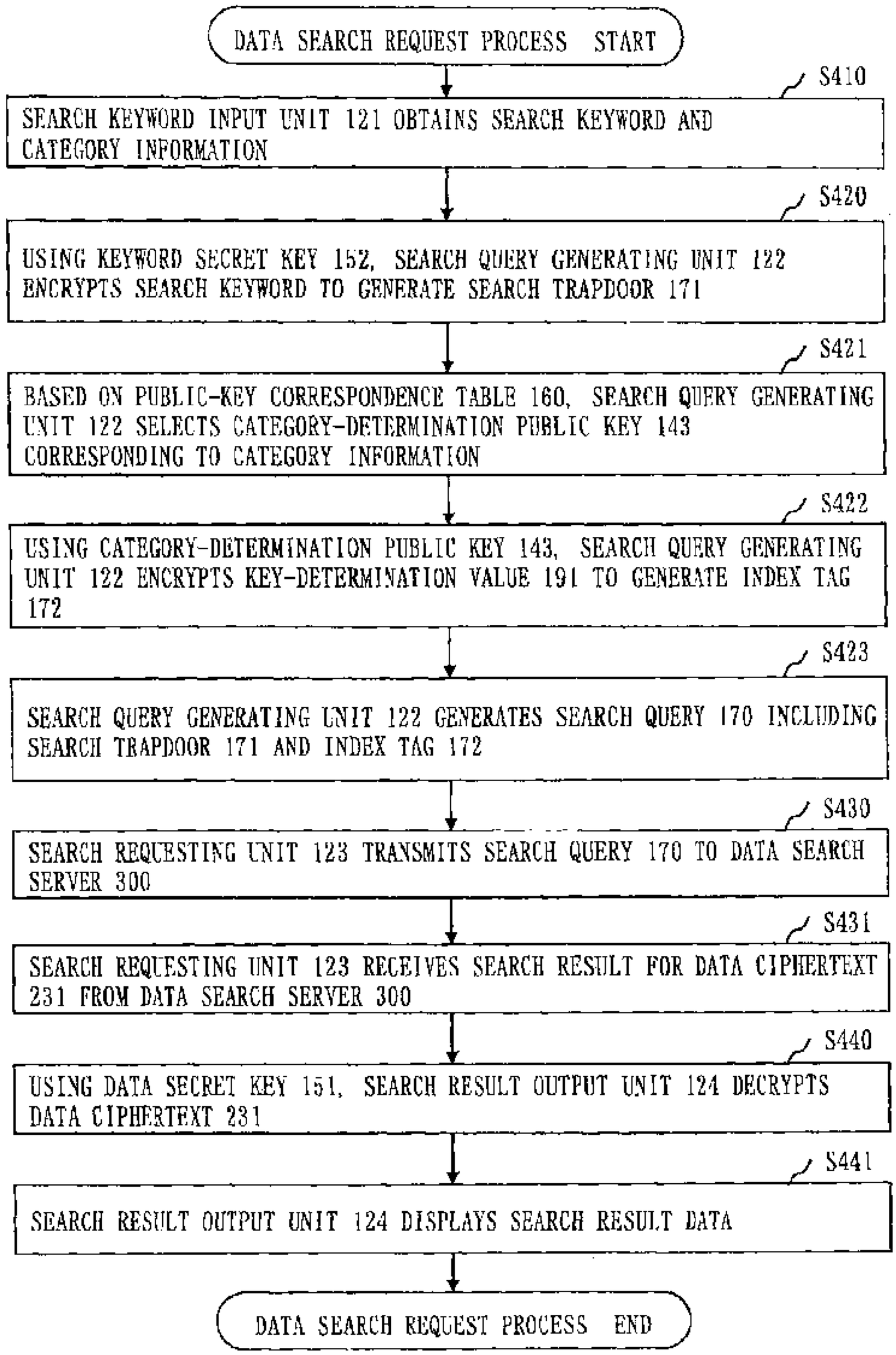

DATA SEARCH REQUEST PROCESS START
S410
SEARCH KEYWORD INPUT UNIT 121 OBTAINS SEARCH KEYWORD AND CATEGORY INFORMATION
S420
USING KEYWORD SECRET KEY 152, SEARCH QUERY GENERATING UNIT 122 ENCRYPTS SEARCH KEYWORD TO GENERATE SEARCH TRAPDOOR 171
S421
BASED ON PUBLIC-KEY CORRESPONDENCE TABLE 160, SEARCH QUERY GENERATING UNIT 122 SELECTS CATEGORY-DETERMINATION PUBLIC KEY 143 CORRESPONDING TO CATEGORY INFORMATION
S422
USING CATEGORY-DETERMINATION PUBLIC KEY 143, SEARCH QUERY GENERATING UNIT 122 ENCRYPTS KEY-DETERMINATION VALUE 191 TO GENERATE INDEX TAG 172
S423
SEARCH QUERY GENERATING UNIT 122 GENERATES SEARCH QUERY 170 INCLUDING SEARCH TRAPDOOR 171 AND INDEX TAG 172
S430
SEARCH REQUESTING UNIT 123 TRANSMITS SEARCH QUERY 170 TO DATA SEARCH SERVER 300
S431
SEARCH REQUESTING UNIT 123 RECEIVES SEARCH RESULT FOR DATA CIPHERTEXT 231 FROM DATA SEARCH SERVER 300
S440
USING DATA SECRET KEY 151, SEARCH RESULT OUTPUT UNIT 124 DECRYPTS DATA CIPHERTEXT 231
S441
SEARCH RESULT OUTPUT UNIT 124 DISPLAYS SEARCH RESULT DATA
DATA SEARCH REQUEST PROCESS END

Fig. 14

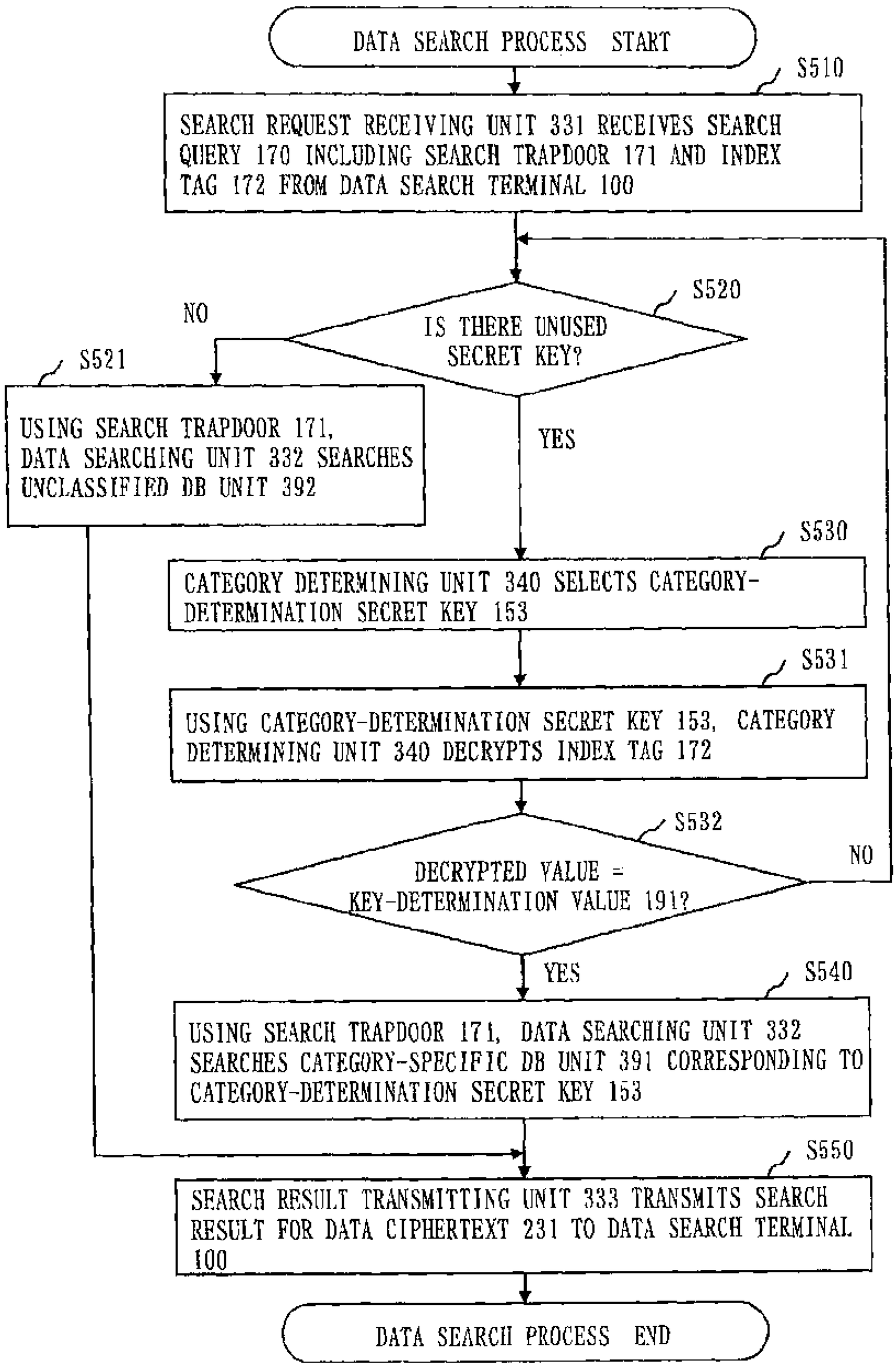

DATA SEARCH PROCESS START
S510
SEARCH REQUEST RECEIVING UNIT 331 RECEIVES SEARCH QUERY 170 INCLUDING SEARCH TRAPDOOR 171 AND INDEX TAG 172 FROM DATA SEARCH TERMINAL 100
S520
IS THERE UNUSED SECRET KEY?
NO
S521
USING SEARCH TRAPDOOR 171, DATA SEARCHING UNIT 332 SEARCHES UNCLASSIFIED DB UNIT 392
YES
S530
CATEGORY DETERMINING UNIT 340 SELECTS CATEGORY-DETERMINATION SECRET KEY 153
S531
USING CATEGORY-DETERMINATION SECRET KEY 153, CATEGORY DETERMINING UNIT 340 DECRYPTS INDEX TAG 172
S532
DECRYPTED VALUE = KEY-DETERMINATION VALUE 191?
NO
YES
S540
USING SEARCH TRAPDOOR 171, DATA SEARCHING UNIT 332 SEARCHES CATEGORY-SPECIFIC DB UNIT 391 CORRESPONDING TO CATEGORY-DETERMINATION SECRET KEY 153
S550
SEARCH RESULT TRANSMITTING UNIT 333 TRANSMITS SEARCH RESULT FOR DATA CIPHERTEXT 231 TO DATA SEARCH TERMINAL 100
DATA SEARCH PROCESS END

Fig. 15

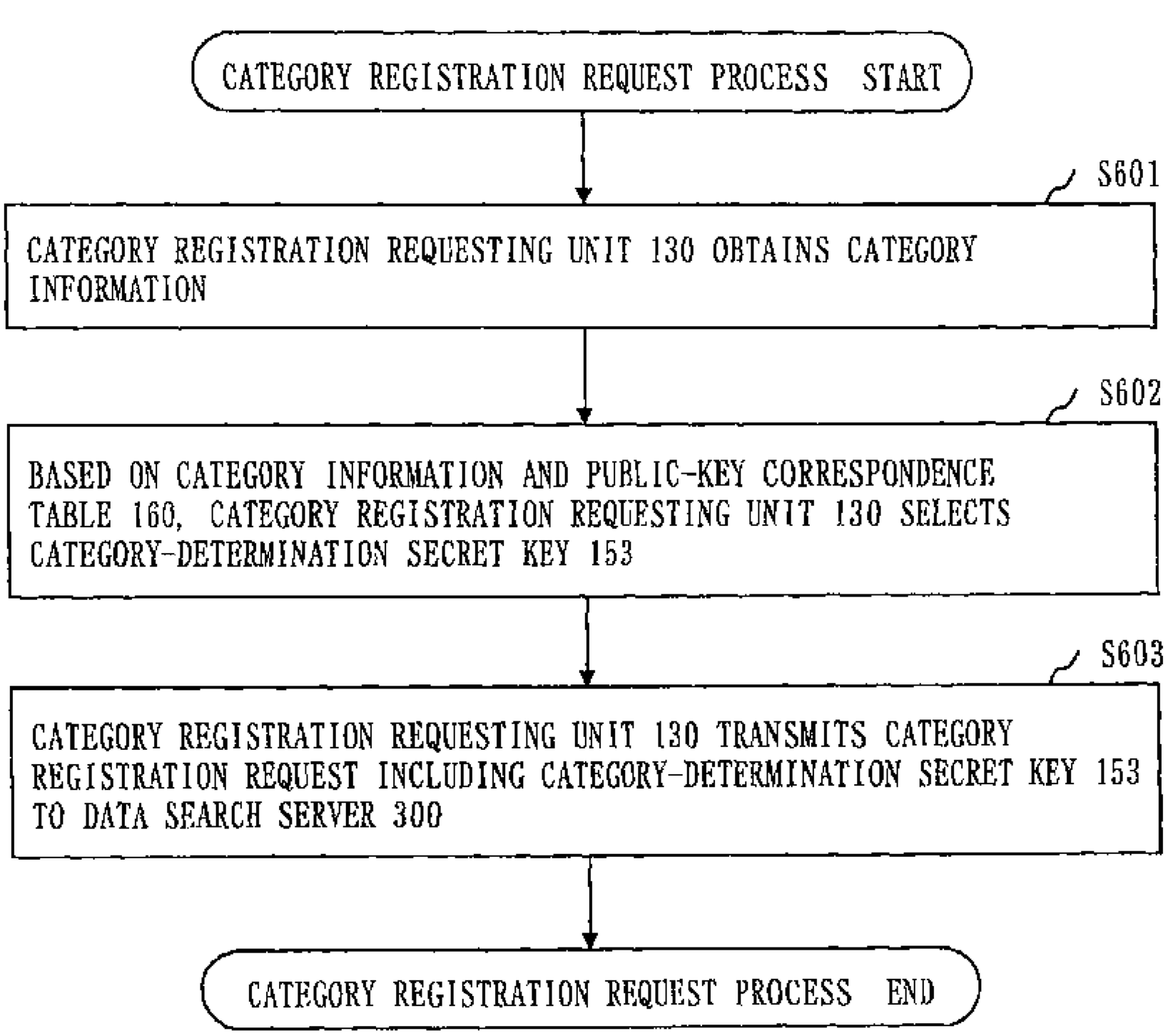

CATEGORY REGISTRATION REQUEST PROCESS START
S601
CATEGORY REGISTRATION REQUESTING UNIT 130 OBTAINS CATEGORY INFORMATION
S602
BASED ON CATEGORY INFORMATION AND PUBLIC-KEY CORRESPONDENCE TABLE 160, CATEGORY REGISTRATION REQUESTING UNIT 130 SELECTS CATEGORY-DETERMINATION SECRET KEY 153
S603
CATEGORY REGISTRATION REQUESTING UNIT 130 TRANSMITS CATEGORY REGISTRATION REQUEST INCLUDING CATEGORY-DETERMINATION SECRET KEY 153 TO DATA SEARCH SERVER 300
CATEGORY REGISTRATION REQUEST PROCESS END

Fig. 16

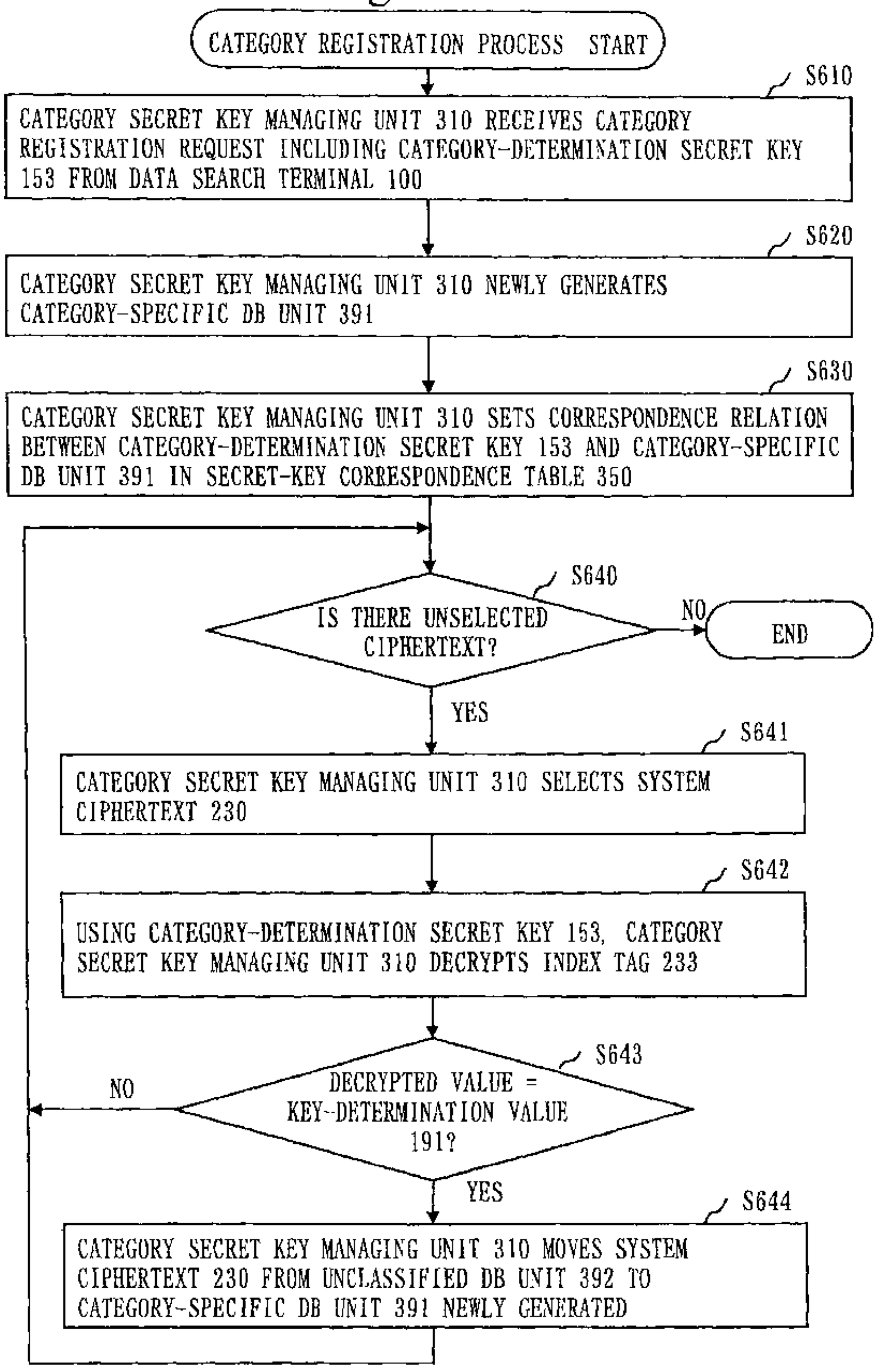

CATEGORY REGISTRATION PROCESS START
S610
CATEGORY SECRET KEY MANAGING UNIT 310 RECEIVES CATEGORY REGISTRATION REQUEST INCLUDING CATEGORY-DETERMINATION SECRET KEY 153 FROM DATA SEARCH TERMINAL 100
S620
CATEGORY SECRET KEY MANAGING UNIT 310 NEWLY GENERATES CATEGORY-SPECIFIC DB UNIT 391
S630
CATEGORY SECRET KEY MANAGING UNIT 310 SETS CORRESPONDENCE RELATION BETWEEN CATEGORY-DETERMINATION SECRET KEY 153 AND CATEGORY-SPECIFIC DB UNIT 391 IN SECRET-KEY CORRESPONDENCE TABLE 350
S640
IS THERE UNSELECTED CIPHERTEXT?
NO
END
YES
S641
CATEGORY SECRET KEY MANAGING UNIT 310 SELECTS SYSTEM CIPHERTEXT 230
S642
USING CATEGORY-DETERMINATION SECRET KEY 153, CATEGORY SECRET KEY MANAGING UNIT 310 DECRYPTS INDEX TAG 233
S643
DECRYPTED VALUE = KEY--DETERMINATION VALUE 191?
NO
YES
S644
CATEGORY SECRET KEY MANAGING UNIT 310 MOVES SYSTEM CIPHERTEXT 230 FROM UNCLASSIFIED DB UNIT 392 TO CATEGORY-SPECIFIC DB UNIT 391 NEWLY GENERATED

Fig. 17

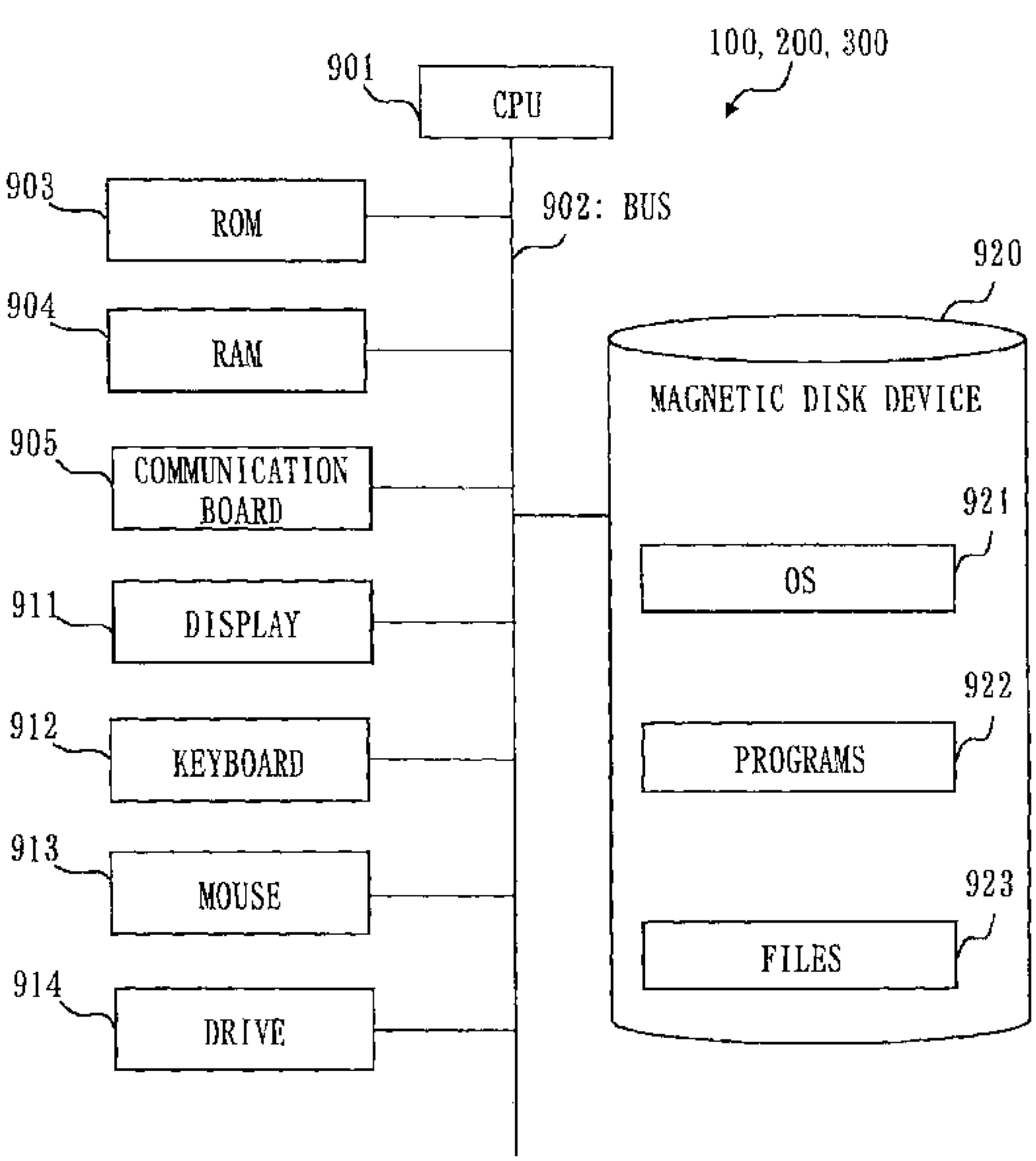

100, 200, 300
901
CPU
903
ROM
902: BUS
920
904
RAM
MAGNETIC DISK DEVICE
905
COMMUNICATION BOARD
921
OS
911
DISPLAY
922
912
KEYBOARD
PROGRAMS
913
MOUSE
923
FILES
914
DRIVE

Fig. 18

192: KEY-DETERMINATION VALUE CORRESPONDENCE TABLE

CATEGORY		KEY-DETERMINATION VALUE
LARGE CLASSIFICATION	SMALL CLASSIFICATION	
PATENT	PRODUCT INVENTION	11
	METHOD INVENTION	12
	• • •	• • •
DESIGN	WHOLE DESIGN	21
	PARTIAL DESIGN	22
	• • •	• • •
• • •	• • •	• • •

Fig. 19

160: PUBLIC-KEY CORRESPONDENCE TABLE

CATEGORY-DETERMINATION PUBLIC KEY	DATE
PK_1	1ST
PK_2	2ND
• • •	• • •

Fig. 20

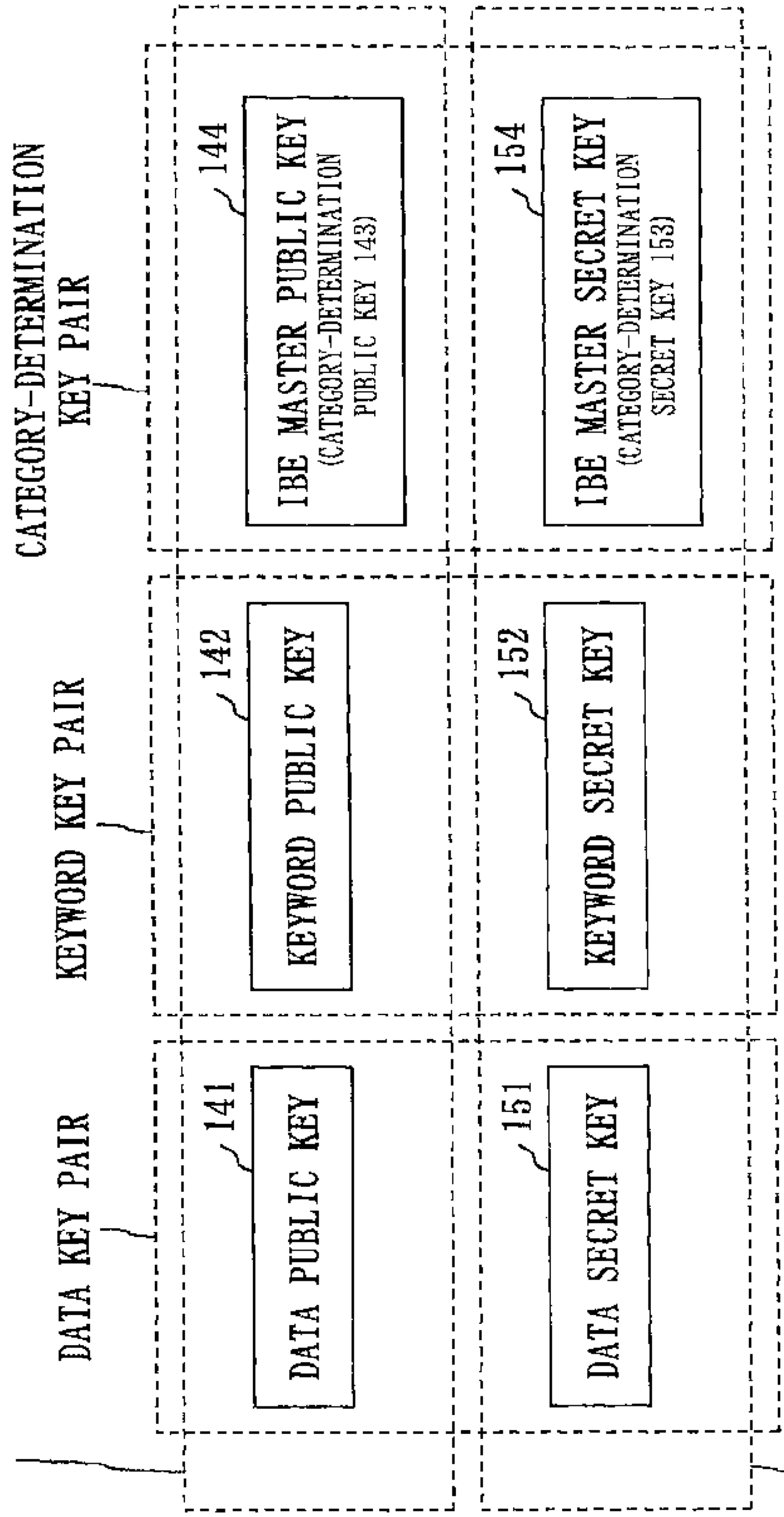

140: SYSTEM PUBLIC KEY
DATA KEY PAIR
141
DATA PUBLIC KEY
KEYWORD KEY PAIR
142
KEYWORD PUBLIC KEY
CATEGORY-DETERMINATION KEY PAIR
144
IBE MASTER PUBLIC KEY
(CATEGORY-DETERMINATION PUBLIC KEY 143)
150: SYSTEM SECRET KEY
DATA KEY PAIR
151
DATA SECRET KEY
KEYWORD KEY PAIR
152
KEYWORD SECRET KEY
CATEGORY-DETERMINATION KEY PAIR
154
IBE MASTER SECRET KEY
(CATEGORY-DETERMINATION SECRET KEY 153)

Fig. 21

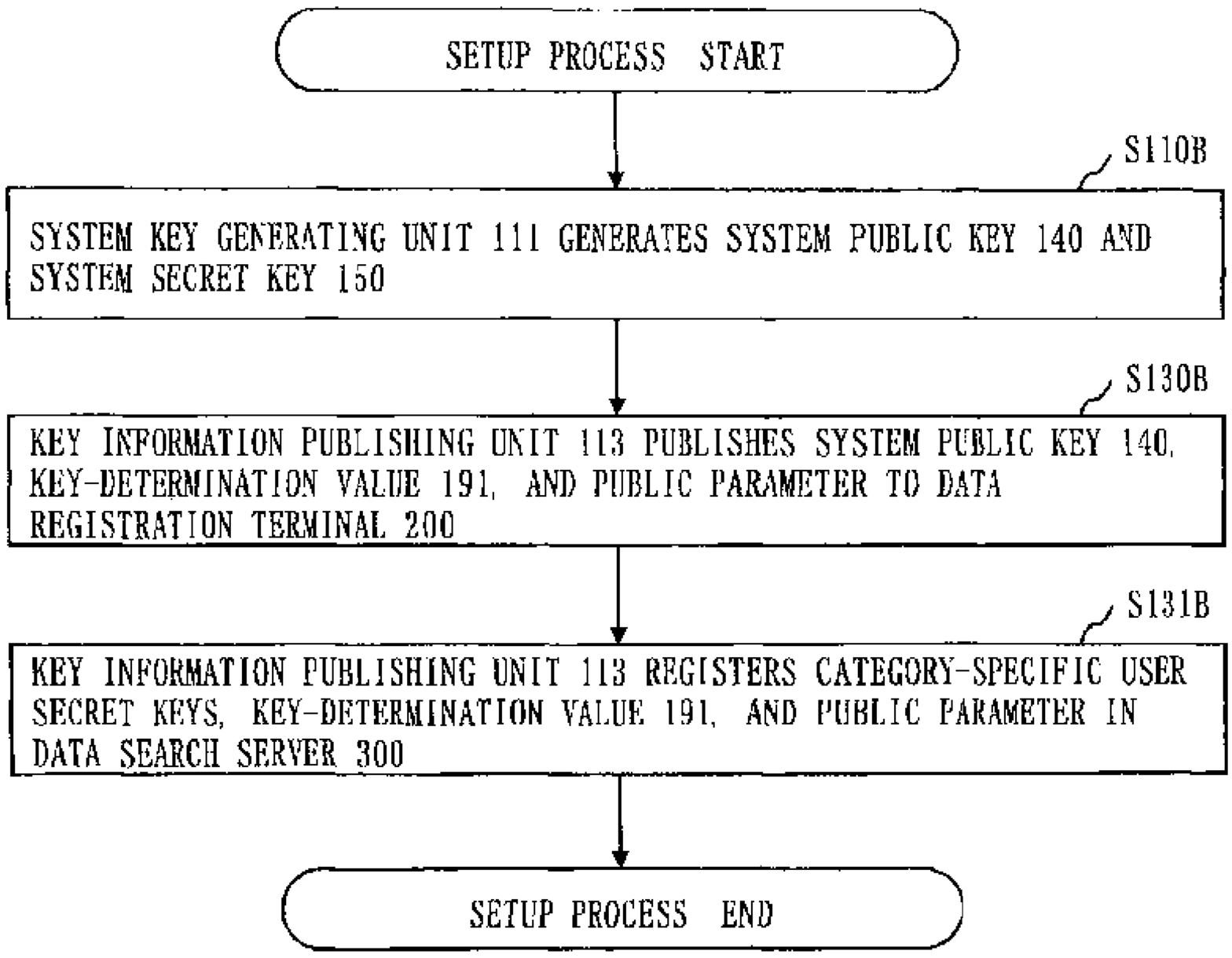

SETUP PROCESS START
S110B
SYSTEM KEY GENERATING UNIT 111 GENERATES SYSTEM PUBLIC KEY 140 AND SYSTEM SECRET KEY 150
S130B
KEY INFORMATION PUBLISHING UNIT 113 PUBLISHES SYSTEM PUBLIC KEY 140, KEY-DETERMINATION VALUE 191, AND PUBLIC PARAMETER TO DATA REGISTRATION TERMINAL 200
S131B
KEY INFORMATION PUBLISHING UNIT 113 REGISTERS CATEGORY-SPECIFIC USER SECRET KEYS, KEY-DETERMINATION VALUE 191, AND PUBLIC PARAMETER IN DATA SEARCH SERVER 300
SETUP PROCESS END

Fig. 22

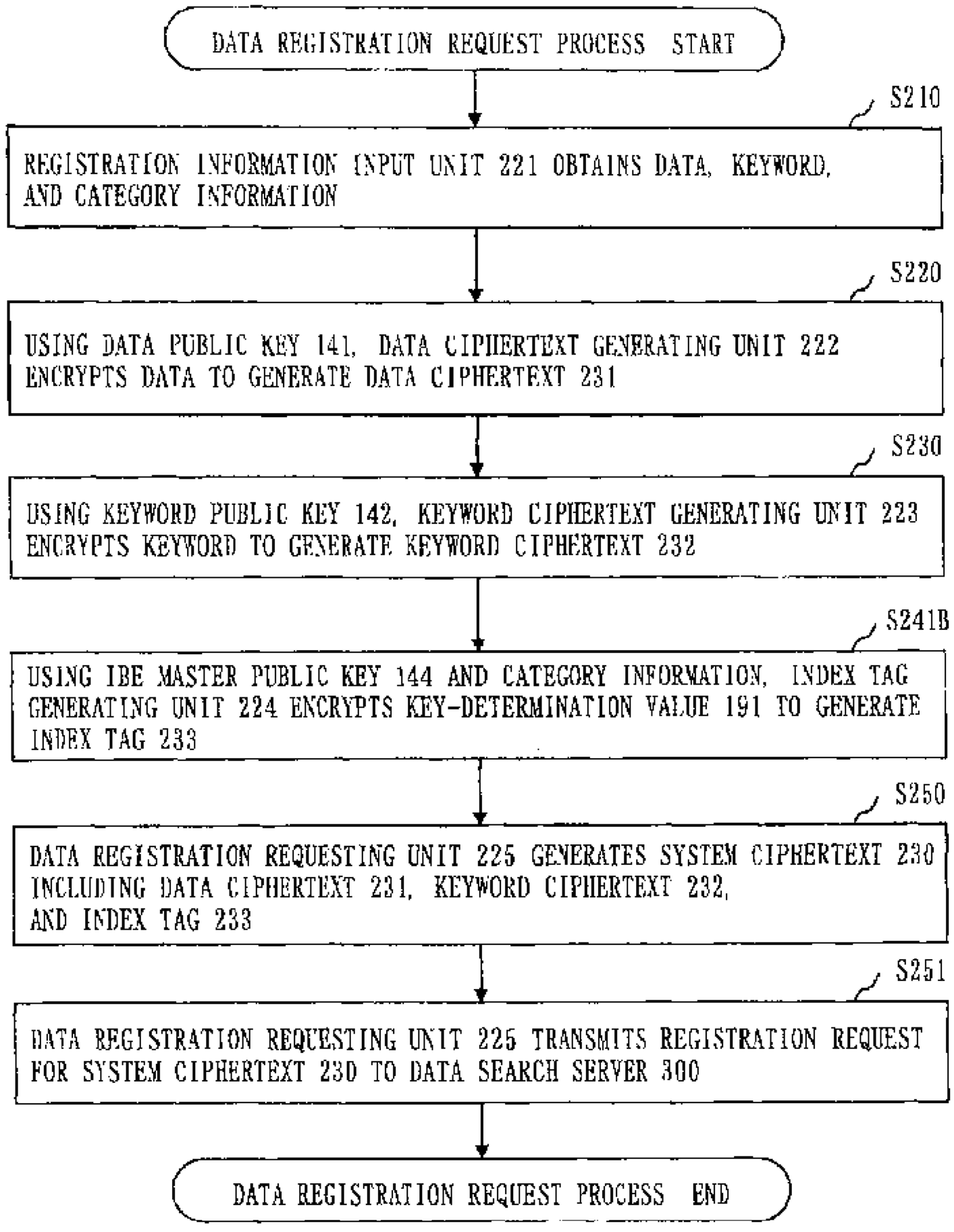

DATA REGISTRATION REQUEST PROCESS START
S210
REGISTRATION INFORMATION INPUT UNIT 221 OBTAINS DATA, KEYWORD, AND CATEGORY INFORMATION
S220
USING DATA PUBLIC KEY 141, DATA CIPHERTEXT GENERATING UNIT 222 ENCRYPTS DATA TO GENERATE DATA CIPHERTEXT 231
S230
USING KEYWORD PUBLIC KEY 142, KEYWORD CIPHERTEXT GENERATING UNIT 223 ENCRYPTS KEYWORD TO GENERATE KEYWORD CIPHERTEXT 232
S241B
USING IBE MASTER PUBLIC KEY 144 AND CATEGORY INFORMATION, INDEX TAG GENERATING UNIT 224 ENCRYPTS KEY-DETERMINATION VALUE 191 TO GENERATE INDEX TAG 233
S250
DATA REGISTRATION REQUESTING UNIT 225 GENERATES SYSTEM CIPHERTEXT 230 INCLUDING DATA CIPHERTEXT 231, KEYWORD CIPHERTEXT 232, AND INDEX TAG 233
S251
DATA REGISTRATION REQUESTING UNIT 225 TRANSMITS REGISTRATION REQUEST FOR SYSTEM CIPHERTEXT 230 TO DATA SEARCH SERVER 300
DATA REGISTRATION REQUEST PROCESS END

Fig. 23

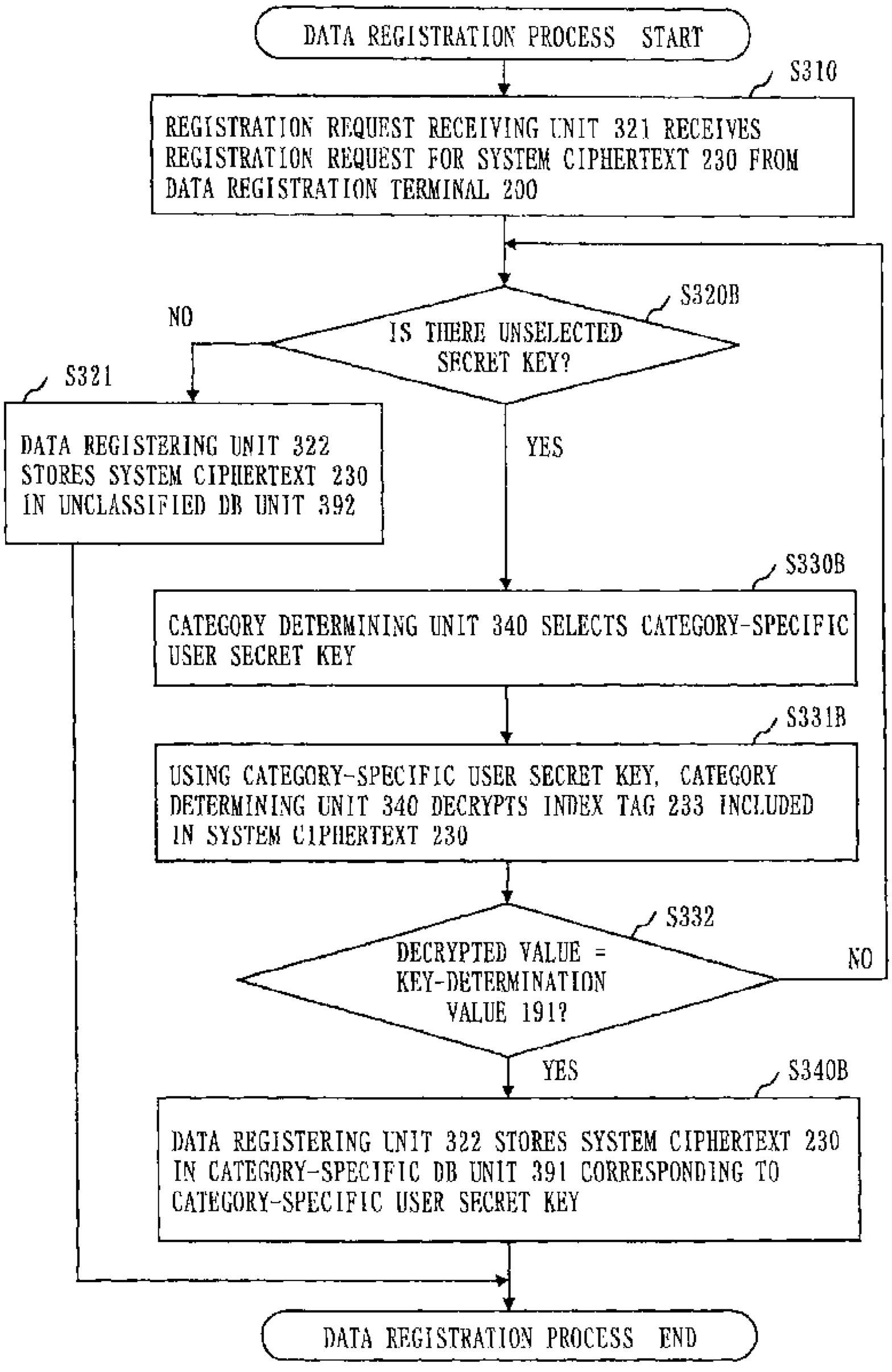

DATA REGISTRATION PROCESS START
S310
REGISTRATION REQUEST RECEIVING UNIT 321 RECEIVES REGISTRATION REQUEST FOR SYSTEM CIPHERTEXT 230 FROM DATA REGISTRATION TERMINAL 200
S320B
IS THERE UNSELECTED SECRET KEY?
NO
S321
DATA REGISTERING UNIT 322 STORES SYSTEM CIPHERTEXT 230 IN UNCLASSIFIED DB UNIT 392
YES
S330B
CATEGORY DETERMINING UNIT 340 SELECTS CATEGORY-SPECIFIC USER SECRET KEY
S331B
USING CATEGORY-SPECIFIC USER SECRET KEY, CATEGORY DETERMINING UNIT 340 DECRYPTS INDEX TAG 233 INCLUDED IN SYSTEM CIPHERTEXT 230
S332
DECRYPTED VALUE = KEY-DETERMINATION VALUE 191?
NO
YES
S340B
DATA REGISTERING UNIT 322 STORES SYSTEM CIPHERTEXT 230 IN CATEGORY-SPECIFIC DB UNIT 391 CORRESPONDING TO CATEGORY-SPECIFIC USER SECRET KEY
DATA REGISTRATION PROCESS END

Fig. 24

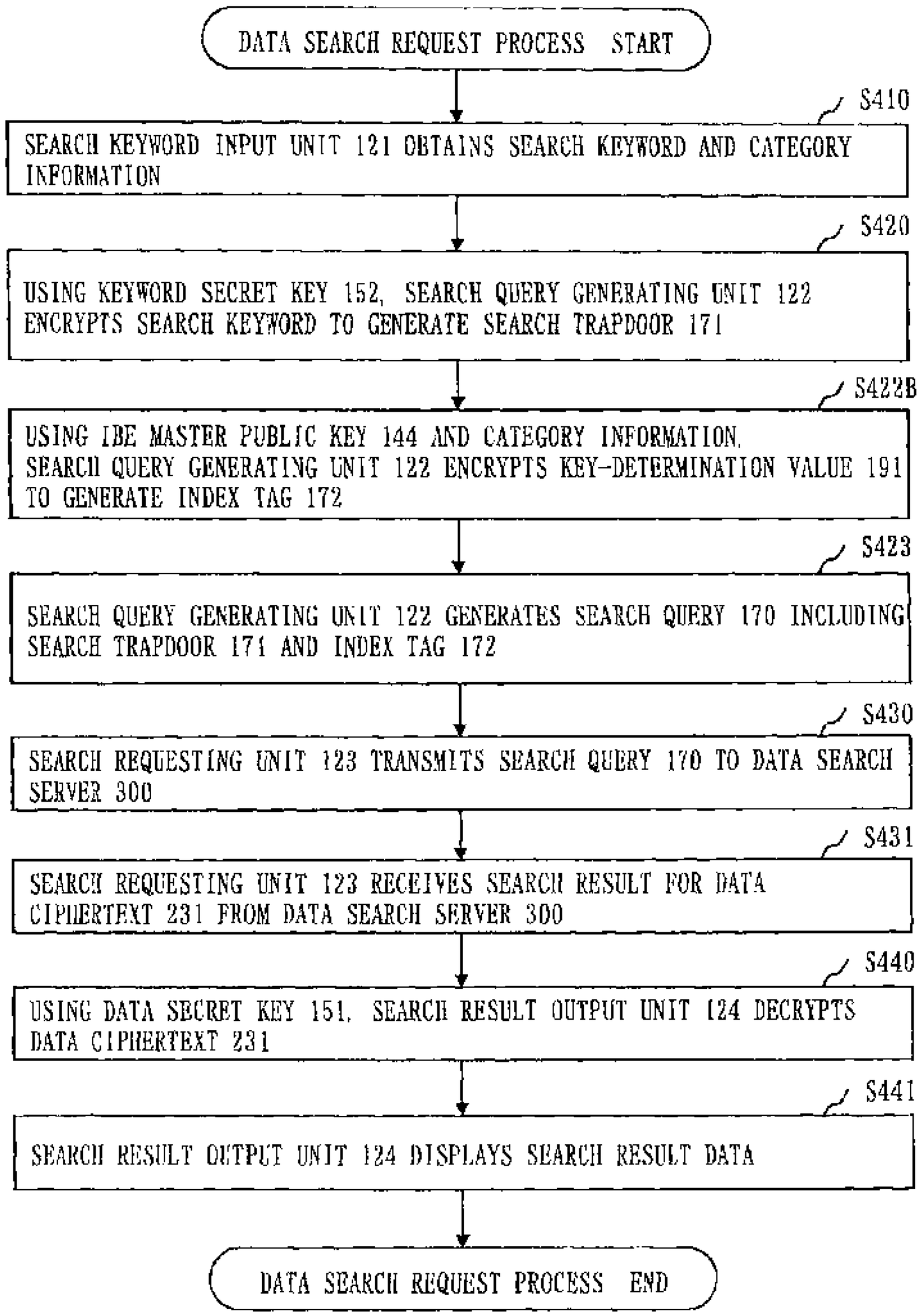

DATA SEARCH REQUEST PROCESS START
S410
SEARCH KEYWORD INPUT UNIT 121 OBTAINS SEARCH KEYWORD AND CATEGORY INFORMATION
S420
USING KEYWORD SECRET KEY 152, SEARCH QUERY GENERATING UNIT 122 ENCRYPTS SEARCH KEYWORD TO GENERATE SEARCH TRAPDOOR 171
S422B
USING IBE MASTER PUBLIC KEY 144 AND CATEGORY INFORMATION, SEARCH QUERY GENERATING UNIT 122 ENCRYPTS KEY-DETERMINATION VALUE 191 TO GENERATE INDEX TAG 172
S423
SEARCH QUERY GENERATING UNIT 122 GENERATES SEARCH QUERY 170 INCLUDING SEARCH TRAPDOOR 171 AND INDEX TAG 172
S430
SEARCH REQUESTING UNIT 123 TRANSMITS SEARCH QUERY 170 TO DATA SEARCH SERVER 300
S431
SEARCH REQUESTING UNIT 123 RECEIVES SEARCH RESULT FOR DATA CIPHERTEXT 231 FROM DATA SEARCH SERVER 300
S440
USING DATA SECRET KEY 151, SEARCH RESULT OUTPUT UNIT 124 DECRYPTS DATA CIPHERTEXT 231
S441
SEARCH RESULT OUTPUT UNIT 124 DISPLAYS SEARCH RESULT DATA
DATA SEARCH REQUEST PROCESS END

Fig. 25

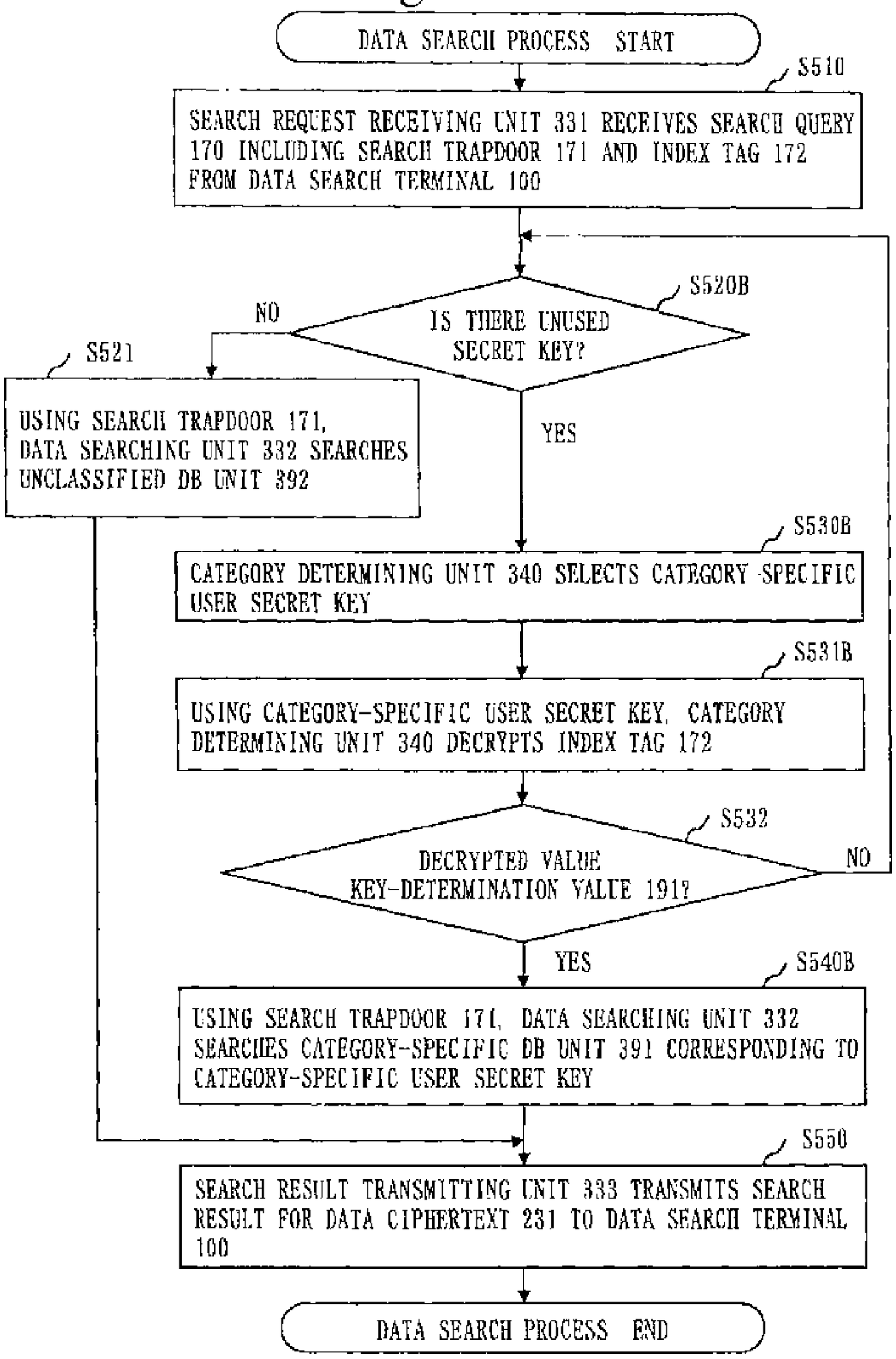

DATA SEARCH PROCESS START
S510
SEARCH REQUEST RECEIVING UNIT 331 RECEIVES SEARCH QUERY 170 INCLUDING SEARCH TRAPDOOR 171 AND INDEX TAG 172 FROM DATA SEARCH TERMINAL 100
S520B
IS THERE UNUSED SECRET KEY?
NO
S521
USING SEARCH TRAPDOOR 171, DATA SEARCHING UNIT 332 SEARCHES UNCLASSIFIED DB UNIT 392
YES
S530B
CATEGORY DETERMINING UNIT 340 SELECTS CATEGORY-SPECIFIC USER SECRET KEY
S531B
USING CATEGORY-SPECIFIC USER SECRET KEY, CATEGORY DETERMINING UNIT 340 DECRYPTS INDEX TAG 172
S532
DECRYPTED VALUE = KEY-DETERMINATION VALUE 191?
NO
YES
S540B
USING SEARCH TRAPDOOR 171, DATA SEARCHING UNIT 332 SEARCHES CATEGORY-SPECIFIC DB UNIT 391 CORRESPONDING TO CATEGORY-SPECIFIC USER SECRET KEY
S550
SEARCH RESULT TRANSMITTING UNIT 333 TRANSMITS SEARCH RESULT FOR DATA CIPHERTEXT 231 TO DATA SEARCH TERMINAL 100
DATA SEARCH PROCESS END

Fig. 26

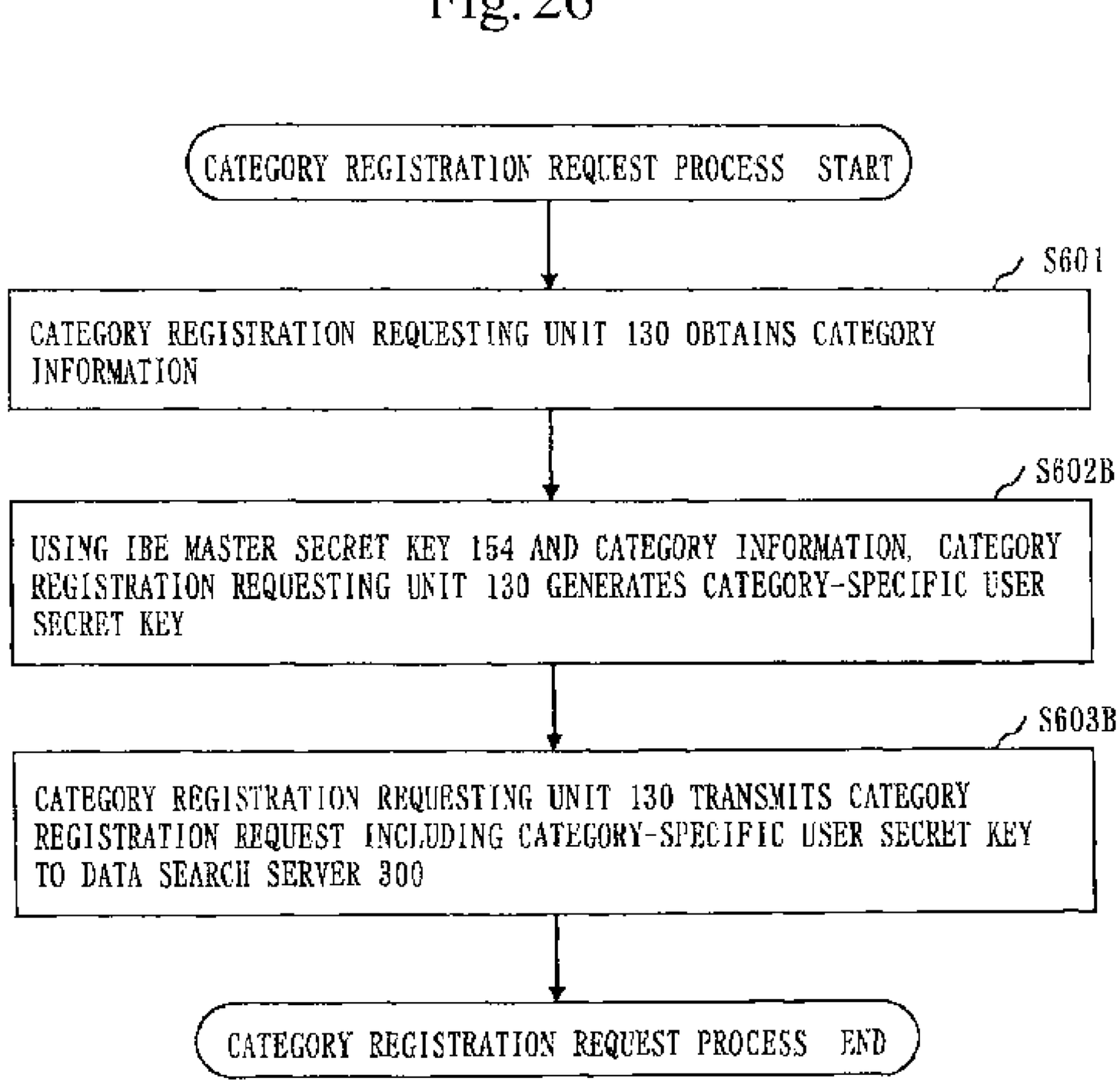

CATEGORY REGISTRATION REQUEST PROCESS START
S601
CATEGORY REGISTRATION REQUESTING UNIT 130 OBTAINS CATEGORY INFORMATION
S602B
USING IBE MASTER SECRET KEY 154 AND CATEGORY INFORMATION, CATEGORY REGISTRATION REQUESTING UNIT 130 GENERATES CATEGORY-SPECIFIC USER SECRET KEY
S603B
CATEGORY REGISTRATION REQUESTING UNIT 130 TRANSMITS CATEGORY REGISTRATION REQUEST INCLUDING CATEGORY-SPECIFIC USER SECRET KEY TO DATA SEARCH SERVER 300
CATEGORY REGISTRATION REQUEST PROCESS END

Fig. 27

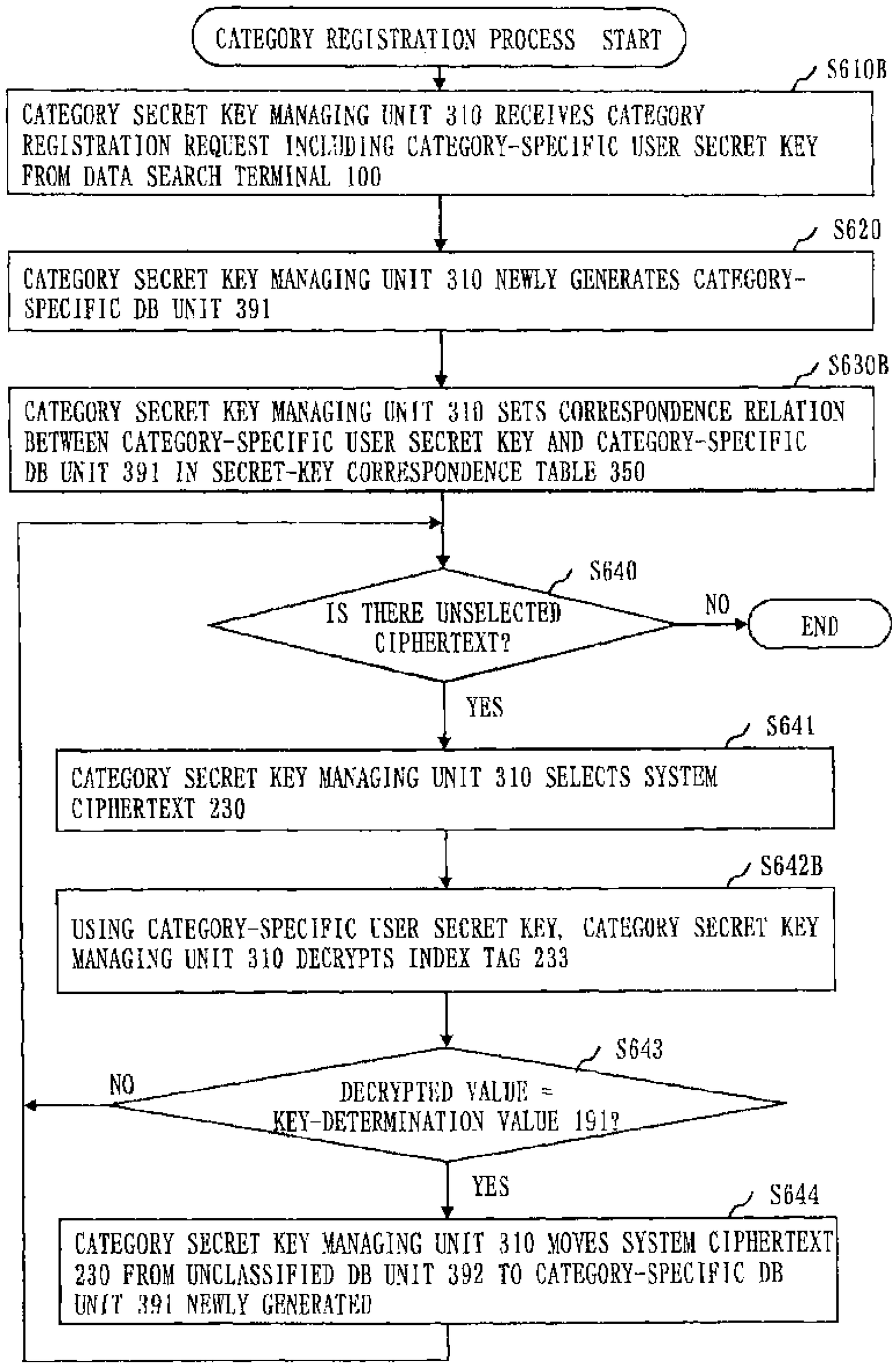
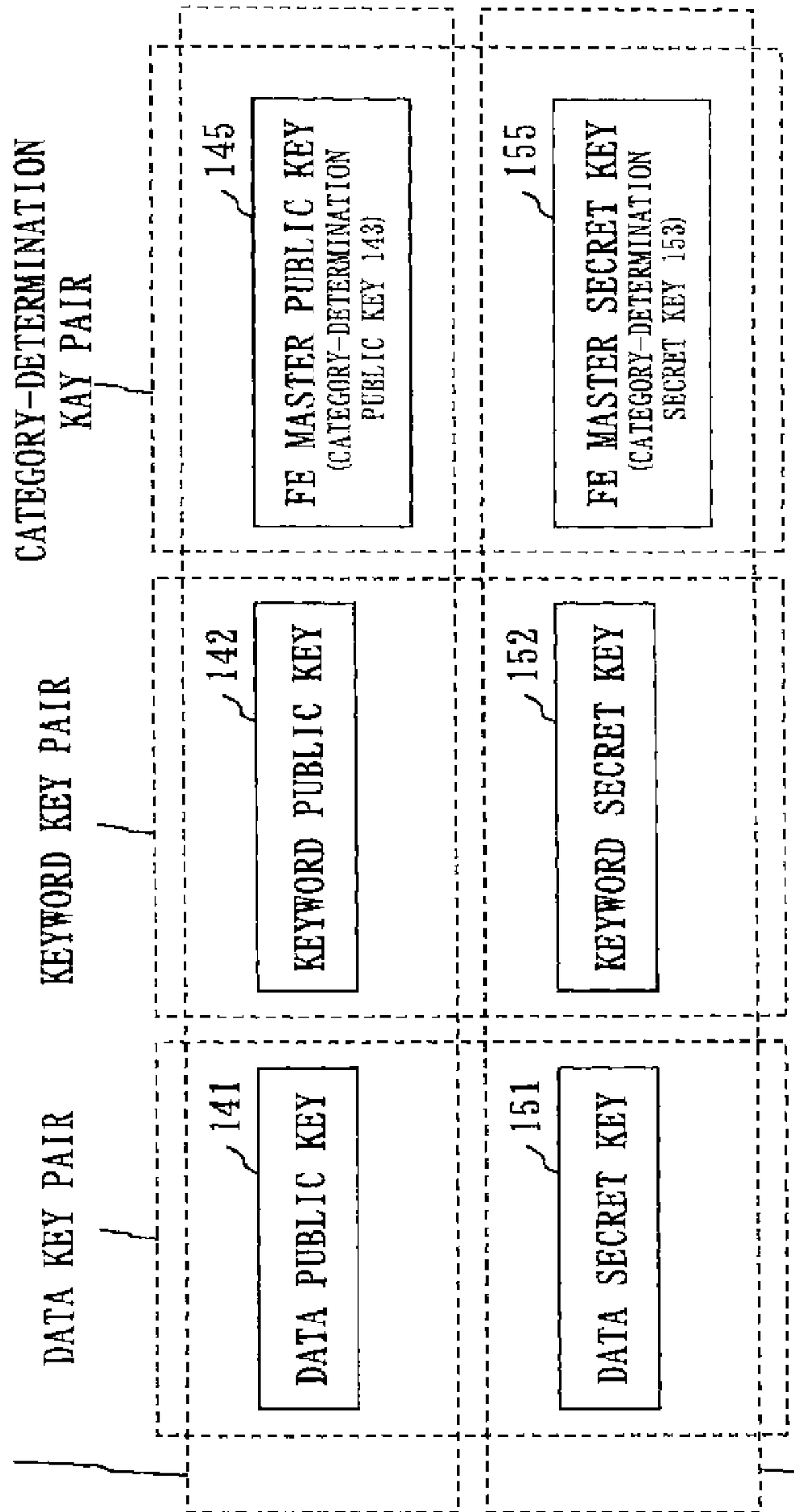

CATEGORY REGISTRATION PROCESS START
S610B
CATEGORY SECRET KEY MANAGING UNIT 310 RECEIVES CATEGORY REGISTRATION REQUEST INCLUDING CATEGORY-SPECIFIC USER SECRET KEY FROM DATA SEARCH TERMINAL 100
S620
CATEGORY SECRET KEY MANAGING UNIT 310 NEWLY GENERATES CATEGORY-SPECIFIC DB UNIT 391
S630B
CATEGORY SECRET KEY MANAGING UNIT 310 SETS CORRESPONDENCE RELATION BETWEEN CATEGORY-SPECIFIC USER SECRET KEY AND CATEGORY-SPECIFIC DB UNIT 391 IN SECRET-KEY CORRESPONDENCE TABLE 350
S640
IS THERE UNSELECTED CIPHERTEXT?
NO
END
YES
S641
CATEGORY SECRET KEY MANAGING UNIT 310 SELECTS SYSTEM CIPHERTEXT 230
S642B
USING CATEGORY-SPECIFIC USER SECRET KEY, CATEGORY SECRET KEY MANAGING UNIT 310 DECRYPTS INDEX TAG 233
S643
DECRYPTED VALUE = KEY-DETERMINATION VALUE 191?
NO
YES
S644
CATEGORY SECRET KEY MANAGING UNIT 310 MOVES SYSTEM CIPHERTEXT 230 FROM UNCLASSIFIED DB UNIT 392 TO CATEGORY-SPECIFIC DB UNIT 391 NEWLY GENERATED

Fig. 28

160: PUBLIC-KEY CORRESPONDENCE TABLE

CATEGORY-DETERMINATION PUBLIC KEY	CATEGORY
ID_1	PATENT
ID_2	DESIGN
...	...

Fig. 29


140: SYSTEM PUBLIC KEY
DATA KEY PAIR
141
DATA PUBLIC KEY
142
KEYWORD PUBLIC KEY
145
FE MASTER PUBLIC KEY
(CATEGORY-DETERMINATION PUBLIC KEY 143)
CATEGORY-DETERMINATION KEY PAIR
KEYWORD KEY PAIR
150: SYSTEM SECRET KEY
DATA KEY PAIR
151
DATA SECRET KEY
152
KEYWORD SECRET KEY
155
FE MASTER SECRET KEY
(CATEGORY-DETERMINATION SECRET KEY 153)

DATA SEARCH DEVICE, DATA SEARCH METHOD, COMPUTER READABLE MEDIUM STORING DATA SEARCH PROGRAM, DATA REGISTRATION DEVICE, DATA REGISTRATION METHOD, COMPUTER READABLE MEDIUM STORING DATA REGISTRATION PROGRAM, AND INFORMATION PROCESSING DEVICE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is an application for reissue of U.S. Pat. No. 9,391,965, issued Jul. 12, 2016, which is a national stage application of PCT/JP2012/051533.

TECHNICAL FIELD

The present invention relates to a data search device, a data search method, a data search program, a data registration device, a data registration method, a data registration program, and an information processing device.

BACKGROUND ART

In the field of Public Key Cryptography (PKC), Public-key Encryption with Keyword Search (PEKS) is known as a technique for performing a keyword search without decrypting encrypted data (see Non-Patent Literature 1).

This PEKS realizes, for example, an application as described below.

Assume a situation where a sender transmits a data file including confidential information to a receiver via an external database (to be referred to as a "server" hereinafter). That is, assume a situation where the sender uploads data files to the server, and the receiver downloads a necessary data file from the server by a keyword search.

It should be noted here that the sender and the receiver wish to share both data files and keywords without revealing them to the server.

The receiver prepares in advance a pair of a public key and a secret key of public-key encryption (to be used for encrypting and decrypting data files) and a pair of a public key and a secret key of PEKS (to be used for encrypting keywords and generating search queries). Then, the receiver publishes both of the public keys.

Using the public key of public-key encryption of the receiver, the sender encrypts a data file to generate a ciphertext of the data file. In addition, using the public key of PEKS, the sender encrypts a keyword to generate a ciphertext of the keyword. The ciphertext of the keyword generated using the public key of PEKS will be hereinafter referred to as an "encrypted tag". The sender uploads the ciphertext of the data file together with the encrypted tag to the server.

Using the secret key of PEKS, the receiver encrypts a keyword to generate a ciphertext of the keyword. The ciphertext of the keyword generated using the secret key of PEKS will be hereinafter referred to as a "trapdoor". The receiver sends this trapdoor to the server as a search query.

Using the received trapdoor, the server performs a secure search on each of encrypted tags of ciphertexts of all data files in a database. Then, the server transmits to the receiver a ciphertext of a data file which has been found as a hit in the secure search.

It has been a problem with PEKS that a search need to be performed on the entirety of data, so that search processing time increases in proportion to the number of data files.

To solve this problem, some methods have been proposed.

Patent Literature 1 discloses a method in which an index storage unit configured to store a keyword and a document name by associating them with each other and an encrypted database configured to store an encrypted document are provided, and a search is performed for a keyword in the index storage unit. If no hit is found in the search, then a search is performed on all documents in the encrypted database. The index storage unit is updated in accordance with a search result.

However, it is a problem with this method that a search needs to be performed on all documents until the index storage unit is updated properly, so that a search process cannot be made faster. It is also a problem with this method that if a large number of various types of search requests occur, the effect of the index storage unit is weakened, so that the search process cannot be made faster. Further, it is a problem with this method that an existing system of a PEKS scheme needs to be changed greatly.

CITATION LIST

Patent Literature

Patent Literature 1: JP 2005-134990 A
Patent Literature 2: WO 2011/086668

Non-Patent Literature

Non-Patent Literature 1: Dan Boneh, Giovanni Di Crescenzo, Rafail Ostrovsky and Giuseppe Persiano, "Public Key Encryption with Keyword Search," Eurocrypt 2004, Lecture Notes in Computer Science, vol. 3027, pp. 506-522, 2004.

Non-Patent Literature 2: Mihir Bellare, Alexandra Boldyreva, Anand Desai and David Pointcheval, "Key-Privacy in Public-Key Encryption," Asiacrypt 2001, Lecture Notes in Computer Science, vol. 2248, pp. 566-582, 2001.

Non-Patent Literature 3: Alfred J. Menezes, Paul C. Van Oorschot, and Scott A. Vanstone, Handbook of Applied Cryptography, Chapter 8 "Public-Key Encryption," CRC Press, 2006.

Non-Patent Literature 4: Dan Boneh and Matthew Franklin, "Identity-Based Encryption from the Weil Pairing," Crypto 2001, Lecture Notes in Computer Science, vol. 2139, pp. 213-229, 2001.

Non-Patent Literature 5: Xavier Boyen and Brent Waters, "Anonymous Hierarchical Identity-Based Encryption (Without Random Oracles)," Crypto 2006, Lecture Notes in Computer Science, vol. 4117, pp. 290-307, 2006.

Non-Patent Literature 6: Michel Abdalla, Mihir Bellare, Dario Catalano, Eike Kiltz, Tadayoshi Kohno, Tanja Lange, John Malone-Lee, Gregory Neven, Pascal Paillier, and Haixia Shi, "Searchable Encryption Revisited: Consistency Properties, Relation to Anonymous IBE, and Extensions," Crypto 2005, Lecture Notes in Computer Science, vol. 3621, pp. 205-222, 2005.

Non-Patent Literature 7: Jonathan Katz, Amit Sahai, and Brent Waters, "Predicate Encryption Supporting Disjunctions, Polynomial Equations, and Inner Products," Eurocrypt 2008, Lecture Notes in Computer Science, vol. 4965, pp. 146-162, 2008.

Non-Patent Literature 8: Tatsuaki Okamoto and Katsuyuki Takashima, "Adaptively Attribute-Hiding (Hierarchical) Inner Product Encryption," Cryptology ePrint Archive, Report 2011/543, 2011.

SUMMARY OF INVENTION

Technical Problem

It is an object of the present invention, for example, to achieve a faster search process using Public-key Encryption with Keyword Search.

Solution to Problem

A data search device according to the present invention includes

a data storage unit configured to store a plurality of data groups, each data group including one or more pieces of data, and a plurality of decryption keys for decrypting encrypted information, by associating each of the plurality of the data groups with each of the plurality of the decryption keys;

a key-determination information storage unit configured to store key-determination information for determining a decryption key;

a search condition input unit configured to obtain a search condition for searching for data, and obtain encrypted information generated by encrypting predetermined information;

a data group selecting unit configured to decrypt the encrypted information obtained by the search condition input unit by using each of the plurality of the decryption keys stored in the data storage unit, select a decryption key with which the encrypted information is decrypted to same information as the key-determination information, from among the plurality of the decryption keys, and select as a search target group a data group associated with the decryption key selected, from among the plurality of the data groups stored in the data storage unit;

a data searching unit configured to obtain as search result data a piece of data that satisfies the search condition obtained by the search condition input unit, from among the one or more pieces of data included in the search target group selected by the data group selecting unit; and

a search result output unit configured to output the search result data obtained by the data searching unit.

Advantageous Effects of Invention

According to the present invention, a faster search process using Public-key Encryption with Keyword Search can be achieved.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a configuration diagram of a data search system **900** in Embodiment 1;

FIG. **2** is a functional configuration diagram of a data search terminal **100** in Embodiment 1;

FIG. **3** is a diagram illustrating a system public key **140** and a system secret key **150** in Embodiment 1;

FIG. **4** is a diagram illustrating a public-key correspondence table **160** in Embodiment 1;

FIG. **5** is a diagram illustrating a search query **170** in Embodiment 1;

FIG. **6** is a functional configuration diagram of a data registration terminal **200** in Embodiment 1;

FIG. **7** is a diagram illustrating a system ciphertext **230** in Embodiment 1;

FIG. **8** is a functional configuration diagram of a data search server **300** in Embodiment 1;

FIG. **9** is a diagram illustrating a secret-key correspondence table **350** in Embodiment 1;

FIG. **10** is a flowchart illustrating a setup process of the data search terminal **100** in Embodiment 1;

FIG. **11** is a flowchart illustrating a data registration process of the data registration terminal **200** in Embodiment 1;

FIG. **12** is a flowchart illustrating a data registration process of the data search server **300** in Embodiment 1;

FIG. **13** is a flowchart illustrating a data search request process of the data search terminal **100** in Embodiment 1;

FIG. **14** is a flowchart illustrating a data search process of the data search server **300** in Embodiment 1;

FIG. **15** is a flowchart illustrating a category registration request process of the data search terminal **100** in Embodiment 1;

FIG. **16** is a flowchart illustrating a category registration process of the data search server **300** in Embodiment 1;

FIG. **17** is a diagram illustrating an example of hardware resources of the data search system **900** in Embodiment 1;

FIG. **18** is a diagram illustrating a key-determination-value correspondence table **192** in Embodiment 1;

FIG. **19** is a diagram illustrating another example of the public-key correspondence table **160** in Embodiment 1;

FIG. **20** is a diagram illustrating a system public key **140** and a system secret key **150** in Embodiment 2;

FIG. **21** is a flowchart illustrating a setup process of the data search terminal **100** in Embodiment 2;

FIG. **22** is a flowchart illustrating a data registration request process of the data registration terminal **200** in Embodiment 2;

FIG. **23** is a flowchart illustrating a data registration process of the data search server **300** in Embodiment 2;

FIG. **24** is a flowchart illustrating a data search request process of the data search terminal **100** in Embodiment 2;

FIG. **25** is a flowchart illustrating a data search process of the data search server **300** in Embodiment 2;

FIG. **26** is a flowchart illustrating a category registration request process of the data search terminal **100** in Embodiment 2;

FIG. **27** is a flowchart illustrating a category registration process of the data search server **300** in Embodiment 2;

FIG. **28** is a diagram illustrating a public-key correspondence table **160** in Embodiment 2; and

FIG. **29** is a diagram illustrating a system public key **140** and a system secret key **150** in Embodiment 3.

DESCRIPTION OF EMBODIMENTS

Embodiment 1

A system that performs a search at high speed using Public-key Encryption with Keyword Search (PEKS) will be described.

PEKS is a technique for performing a keyword search without decrypting encrypted data (see Non-Patent Literature 1).

FIG. **1** is a configuration diagram of a data search system **900** in Embodiment 1.

Referring to FIG. **1**, a configuration of the data search system **900** in Embodiment 1 will be described.

The data search system **900** is an example of a system that performs a search using PEKS. By using PEKS, a keyword search can be performed with search target data and a search keyword being kept secret.

The data search system **900** includes one data search terminal **100**, a plurality of data registration terminals **200**, and one data search server **300**. However, there may be a plurality of the data search terminals **100** and a plurality of the data search servers **300**, and there may be one data registration terminal **200**.

The data search terminal **100**, the data registration terminals **200**, and the data search server **300** are connected for communication via a network **909** (e.g., the Internet).

The data registration terminal **200** (an example of a data registration device) is a device (computer) configured to encrypt search target data and register the encrypted data in the data search server **300**.

The data search terminal **100** (an example of an information processing terminal device) is a device configured to request a keyword search to the data search server **300** by specifying an encrypted search keyword.

The data search server **300** (an example of a data search device) is a device configured to perform a keyword search of PEKS on encrypted data registered by the data registration terminal **200**, in accordance with an encrypted keyword specified by the data search terminal **100**. The data search server **300** returns a search result to the data search terminal **100**.

For example, the search target data may be electronic mail messages. In this case, the data search server **300** functions as a mail server, the data registration terminal **200** functions as a computer used by a sender of electronic mail messages, and the data search terminal **100** functions as a computer used by a receiver of electronic mail messages. Then, the data search system **900** is used as described below. Note that the following is an example of a method for using the data search system **900**.

Each of senders A, B, and C of electronic mail messages transmits to the data search server **300** an electronic mail message encrypted using the data registration terminal **200**. The data search server **300** stores the encrypted electronic mail messages from the senders A, B, and C.

If the receiver of electronic mail messages wishes to view the electronic mail message of the sender A, the receiver specifies to the data search terminal **100** an identifier (e.g., electronic mail address) of the sender A as a search keyword for the electronic mail message. The data search terminal **100** encrypts the search keyword (identifier of the sender A), and transmits the encrypted search keyword to the data search server **300**.

The data search server **300** performs a keyword search of PEKS in accordance with the encrypted search keyword, and transmits the encrypted electronic mail message of the sender A to the data search terminal **100**.

The data search terminal **100** receives the encrypted electronic mail message of the sender A, decrypts the received electronic mail message, and displays the decrypted electronic mail message.

With this arrangement, the senders A, B, and C and the receiver of electronic mail messages can keep electronic mail messages secret. Furthermore, the receiver of electronic mail messages can keep search keywords for electronic mail messages secret.

FIG. **2** is a functional configuration diagram of the data search terminal **100** in Embodiment 1.

Referring to FIG. **2**, a functional configuration of the data search terminal **100** in Embodiment 1 will be described.

The data search terminal **100** (an example of an information processing device) includes a setup processing unit **110**, a search request processing unit **120**, a category registration requesting unit **130**, and a search-terminal storage unit **190**.

The setup processing unit **110** includes a system key generating unit **111**, a public-key correspondence table generating unit **112**, and a key information publishing unit **113**.

The system key generating unit **111** generates a key-determination value **191**, a system public key **140**, and a system secret key **150** to be described later.

The public-key correspondence table generating unit **112** generates a public-key correspondence table **160** to be described later.

The key information publishing unit **113** publishes the system public key **140**, the system secret key **150**, and the public-key correspondence table **160** to the data registration terminal **200** or the data search server **300**.

The system key generating unit **111**, the public-key correspondence table generating unit **112**, and the key information publishing unit **113** will be described in detail with reference to a flowchart of a setup process to be described later.

FIG. **3** is a diagram illustrating the system public key **140** and the system secret key **150** in Embodiment 1.

Referring to FIG. **3**, the system public key **140** and the system secret key **150** in Embodiment 1 will be described.

The system public key **140** and the system secret key **150** constitute a key pair of public-key encryption (or PEKS) which are used in the data search system **900**.

The system public key **140** includes one data public key **141**, one keyword public key **142**, and a plurality of category-determination public keys **143** (an example of a plurality of encryption keys).

The data public key **141** is key data (encryption key) for encrypting search target data.

The keyword public key **142** is key data (encryption key) for encrypting a keyword (data keyword) to be attached to search target data or a keyword (search keyword) specified when searching for data.

Each category-determination public key **143** is key data (encryption key) for encrypting information (key-determination value **191**) for determining a category (data category) to which search target data belongs. The category-determination public key **143** is different for each data category.

The system secret key **150** includes one data secret key **151**, one keyword secret key **152**, and a plurality of category-determination secret keys **153** (an example of a plurality of decryption keys).

The data secret key **151** is key data (decryption key) for decrypting encrypted search target data.

The keyword secret key **152** is key data (master secret key) for generating a secret key (search trapdoor **171** to be described later) corresponding to a search keyword.

Each category-determination secret key **153** is key data (decryption key) for decrypting an encrypted key-determination value **191** (index tag **172** or index tag **233** to be described later). The category-determination secret key **153** is different for each data category.

The data public key **141** and the data secret key **151** constitute a key pair (key pair of public-key encryption) for data.

The keyword public key **142** and the keyword secret key **152** constitute a key pair (key pair of PEKS) for data

keywords. The keyword public key **142** and the keyword secret key **152** may be used also as a key pair for data. In this case, the data public key **141** and the data secret key **151** are not needed.

The category-determination public keys **143** and the category-determination secret keys **153** constitute a plurality of key pairs (key pairs of public-key encryption) for determining data categories.

FIG. **4** is a diagram illustrating the public-key correspondence table **160** in Embodiment 1.

Referring to FIG. **4**, the public-key correspondence table **160** in Embodiment 1 will be described.

The public-key correspondence table **160** is data associating each category-determination public key **143** with a data category.

In the public-key correspondence table **160** shown in FIG. **4**, a category-determination public key **143** identified by "PK_1" is associated with a "patent" category, and a category-determination public key **143** identified by "PK_2" is associated with a "design" category.

Referring back to FIG. **2**, the functional configuration of the data search terminal **100** will be further described.

The search request processing unit **120** includes a search keyword input unit **121**, a search query generating unit **122**, a search requesting unit **123**, and a search result output unit **124**.

The search keyword input unit **121** (an example of a search condition input unit) obtains from an input device or a storage device a search keyword (an example of a search condition) and a search target category that are specified by a user (data searcher).

The search query generating unit **122** (an example of an encrypted tag generating unit) generates a search query **170** based on the search keyword and the search target category. The search query **170** is data for specifying a search keyword.

The search requesting unit **123** (an example of a data search requesting unit) transmits the search query **170** to the data search server **300**, and receives a search result **199** including encrypted data corresponding to the search keyword from the data search server **300**.

The search result output unit **124** decrypts the encrypted data included in the search result **199** by using the data secret key **151**, and outputs decrypted data.

The search keyword input unit **121**, the search query generating unit **122**, the search requesting unit **123**, and the search result output unit **124** will be described in detail with reference to a flowchart of a data search request process to be described later.

FIG. **5** is a diagram illustrating the search query **170** in Embodiment 1.

Referring to FIG. **5**, the search query **170** in Embodiment 1 will be described.

The search query **170** is data including a search trapdoor **171** (an example of search condition information) and an index tag **172** (an example of an encrypted tag).

The search trapdoor **171** is a secret key corresponding to a search keyword. The search trapdoor **171** is generated using the keyword secret key **152**.

The index tag **172** is an encrypted key-determination value **191** encrypted using a category-determination public key **143** of a search target category.

Referring back to FIG. **2**, the functional configuration of the data search terminal **100** will be further described.

The category registration requesting unit **130** requests the data search server **300** to generate a database for data belonging to a specific category.

The category registration requesting unit **130** will be described in detail with reference to a flowchart of a category registration request process to be described later.

The search-terminal storage unit **190** (an example of an encryption key storage unit) stores data used in the data search terminal **100**.

For example, the search-terminal storage unit **190** stores the key-determination value **191**, the system public key **140**, the system secret key **150**, the public-key correspondence table **160**, the search query **170**, and the search result **199**.

FIG. **6** is a functional configuration diagram of the data registration terminal **200** in Embodiment 1.

Referring to FIG. **6**, a functional configuration of the data registration terminal **200** in Embodiment 1 will be described.

The data registration terminal **200** (an example of the data registration device) includes a public information acquisition unit **210**, a data registration request processing unit **220**, and a registration-terminal storage unit **290**.

The public information acquisition unit **210** obtains the key-determination value **191**, the system public key **140**, and the public-key correspondence table **160** published by the data search terminal **100**.

The public information acquisition unit **210** will be described in detail with reference to the flowchart of the setup process to be described later.

The data registration request processing unit **220** includes a registration information input unit **221**, a data ciphertext generating unit **222**, a keyword ciphertext generating unit **223**, an index tag generating unit **224**, and a data registration requesting unit **225**.

The registration information input unit **221** (an example of a classification information input unit) obtains from an input device or a storage device data, a data keyword, and a data category that are specified by a user (data registering person).

The data ciphertext generating unit **222** (an example of a data generating unit) encrypts the data using the data public key **141**.

The keyword ciphertext generating unit **223** encrypts the data keyword using the keyword public key **142**.

The index tag generating unit **224** (an example of the encrypted tag generating unit) encrypts the key-determination value **191** using the category-determination public key **143** of the data category.

The data registration requesting unit **225** (an example of a data registration requesting unit) requests the data search server **300** to register a system ciphertext **230** including the data, the keyword and the key-determination value **191** that have been encrypted.

The registration information input unit **221**, the data ciphertext generating unit **222**, the keyword ciphertext generating unit **223**, the index tag generating unit **224**, and the data registration requesting unit **225** will be described in detail with reference to a flowchart of a data registration request process to be described later.

FIG. **7** is a diagram illustrating the system ciphertext **230** in Embodiment 1.

Referring to FIG. **7**, the system ciphertext **230** in Embodiment 1 will be described.

The system ciphertext **230** is data including a data ciphertext **231**, a keyword ciphertext **232**, and an index tag **233**.

The data ciphertext **231** (an example of data) is generated by encrypting data using the data public key **141**.

The keyword ciphertext **232** is generated by encrypting a data keyword using the keyword public key **142**.

The index tag **233** (an example of the encrypted tag) is generated by encrypting the key-determination value **191** using the category-determination public key **143** of a category to which the data belongs.

Referring back to FIG. **6**, the functional configuration of the data registration terminal **200** will be further described.

The registration-terminal storage unit **290** stores data used in the data registration terminal **200**.

For example, the registration-terminal storage unit **290** stores the key-determination value **191**, the system public key **140**, the public-key correspondence table **160**, and the system ciphertext **230**.

FIG. **8** is a functional configuration diagram of the data search server **300** in Embodiment 1.

Referring to FIG. **8**, a functional configuration of the data search server **300** in Embodiment 1 will be described.

The data search server **300** (an example of the data search device) includes a category secret key managing unit **310**, a data registration processing unit **320**, a data search processing unit **330**, a category determining unit **340**, and a search-server storage unit **390**.

The data search server **300** further includes a database for each data category (to be referred to as a "category-specific DB unit **391**" hereinafter).

The data search server **300** also includes a database for data not classified into any category (to be referred to as an "unclassified DB unit **392**" hereinafter).

The category secret key managing unit **310** (an example of an additional decryption key input unit and a data group registering unit) manages the key-determination value **191** and the category-determination secret keys **153** that are generated by the data search terminal **100**.

The category secret key managing unit **310** also generates a category-specific DB unit **391** to be associated with each category-determination secret key **153**.

The category secret key managing unit **310** further generates a secret-key correspondence table **350** associating each category-determination secret key **153** with each category-specific DB unit **391**.

The category secret key managing unit **310** will be described in detail with reference to the flowchart of the setup process and a flowchart of a category registration process to be described later.

The data registration processing unit **320** includes a registration request receiving unit **321** and a data registering unit **322**.

The registration request receiving unit **321** (an example of a new data input unit) receives a registration request for data (the system ciphertext **230** shown in FIG. **7**) transmitted from the data registration terminal **200**.

The data registering unit **322** (an example of a new data registering unit) stores the data in the category-specific DB unit **391** of the category to which the data belongs, in accordance with the registration request for the data.

The registration request receiving unit **321** and the data registering unit **322** will be described in detail with reference to a flowchart of a data registration process to be described later.

The data search processing unit **330** includes a search request receiving unit **331**, a data searching unit **332**, and a search result transmitting unit **333**.

The search request receiving unit **331** (an example of the search condition input unit) receives a search request for data (the search query shown in FIG. **5**) transmitted from the data search terminal **100**.

The data searching unit **332** (an example of a data searching unit) searches the category-specific DB unit **391** of a search target category, in accordance with the search request for the data.

The search result transmitting unit **333** (an example of a search result output unit) transmits a search result including data (the system ciphertext **230** shown in FIG. **7**) that satisfies a search condition to the data search terminal **100**.

The search request receiving unit **331**, the data searching unit **332**, and the search result transmitting unit **333** will be described in detail with reference to a flowchart of a data search process to be described later.

The category determining unit **340** (an example of a data group selecting unit) determines the category-specific DB unit **391** of the category to which the data belongs based on the registration request for the data, and determines the category-specific DB unit **391** of the search target category based on the search request for the data.

The category determining unit **340** will be described in detail with reference to the flowchart of the data registration process and the flowchart of the data search process to be described later.

The search-server storage unit **390** stores data used in the data search server **300**.

For example, the search-server storage unit **390** stores the key-determination value **191**, the category-determination secret keys **153**, and the secret-key correspondence table **350**.

FIG. **9** is a diagram illustrating the secret-key correspondence table **350** in Embodiment 1.

Referring to FIG. **9**, the secret-key correspondence table **350** in Embodiment 1 will be described.

The secret-key correspondence table **350** is data associating each category-determination secret key **153** with a category-specific DB unit **391**.

In the secret-key correspondence table **350** shown in FIG. **9**, a category-determination secret key **153** identified by "SK_1." is associated with a category-specific DB unit **391** identified by "DB_1", and a category-determination secret key **153** identified by "SK_2" is associated with a category-specific DB unit **391** identified by "DB_2".

Referring back to FIG. **8**, the functional configuration of the data search server **300** will be further described.

Each category-specific DB unit **391** (an example of a data storage unit) stores one or more system ciphertexts **230** that have been classified into the same category (an example of a data group).

The unclassified DB unit **392** (an example of the data storage unit) stores one or more system ciphertexts **230** that have not been classified into any category (an example of an unclassified group).

FIG. **10** is the flowchart illustrating the setup process of the data search terminal **100** in Embodiment 1.

Referring to FIG. **10**, the setup process of the data search terminal **100** in Embodiment 1 will be described.

A user who wishes to perform a data search (to be referred to as a "searcher" hereinafter) activates the setup processing unit **110** of the data search terminal **100**, and the setup processing unit **110** of the data search terminal **100** executes the setup process (S**110** to S**131**) described below.

In S**110**, the system key generating unit **111** generates a system public key **140** and a system secret key **150** (see FIG. **3**). For a key generation method, refer to Non-Patent Literature 3.

At this time, the system key generating unit **111** generates a key pair of a data public key **141** and a data secret key **151** using a key generation algorithm of a public-key encryption

scheme. RSA encryption (RSA is a registered trademark) is an example of the public-key encryption scheme.

The system key generating unit **111** also generates a key pair of a keyword public key **142** and a keyword secret key **152** using a key generation algorithm of a PEKS scheme.

The system key generating unit **111** also generates a plurality of key pairs of category-determination public keys **143** and category-determination secret keys **153** using a key generation algorithm of a public-key encryption scheme. For example, the system key generating unit **111** uses a public-key encryption scheme with key-privacy, such as ElGamal encryption or Cramer-Shoup encryption. Key-privacy refers to the property that the public key used cannot be known by looking at a ciphertext. The number of key pairs of the category-determination public keys **143** and the category-determination secret keys **153** is the number of categories for data classification, and is specified (input) by the searcher to the system key generating unit **111** of the data search terminal **100**.

After S**110**, processing proceeds to S**120**.

In S**120**, using an input device (e.g., a keyboard or a mouse), the searcher inputs to the public-key correspondence table generating unit **112** of the data search terminal **100** category information indicating a data category to be associated with each category-determination public key **143** generated in S**110**. That is, the public-key correspondence table generating unit **112** obtains from the input device the category information specified by the searcher.

In accordance with the category information that has been input, the public-key correspondence table generating unit **112** generates a public-key correspondence table **160** as shown in FIG. **4**. The public-key correspondence table **160** is data associating each category-determination public key **143** with a data category.

For example, when the data category to be associated with the category-determination public key **143** identified by "PK_1" is "patent", the public-key correspondence table generating unit **112** associates "PK_1" with "patent" and sets them in the public-key correspondence table **160**.

After S**120**, processing proceeds to S**130**.

In S**130**, the key information publishing unit **113** publishes a key-determination value **191** which is predetermined, the system public key **140** generated in S**110**, and the public-key correspondence table **160** generated in S**120**, as public information to the data registration terminal **200**. The key-determination value **191** is a predetermined value (e.g., "1").

For example, the key information publishing unit **113** of the data search terminal **100** registers the public information with a predetermined server (e.g., the data search server **300**), and the public information acquisition unit **210** of the data registration terminal **200** obtains the public information from the predetermined server. The public information acquisition unit **210** stores the obtained public information in the registration-terminal storage unit **290**.

Alternatively, for example, the public information acquisition unit **210** of the data registration terminal **200** transmits a publication request for requesting the public information to the data search terminal **100**, and the key information publishing unit **113** of the data search terminal **100** receives the publication request. Then, the key information publishing unit **113** of the data search terminal **100** transmits the public information to the data registration terminal **200**, and the public information acquisition unit **210** of the data registration terminal **200** receives the public information. The public information acquisition unit **210** stores the received public information in the registration-terminal storage unit **290**.

After S**130**, processing proceeds to S**131**.

In S**131**, the key information publishing unit **113** transmits to the data search server **300** the key-determination value **191** which is predetermined and a plurality of the category-determination secret keys **153** generated in S**110**. The key-determination value **191** is the same as the value published to the data registration terminal **200**.

Note that the key information publishing unit **113** may only transmit at least any one of the plurality of the category-determination secret keys **153** to the data search server **300**. That is, there may be category-determination secret keys **153** which are not transmitted to the data search server **300**. For example, the searcher specifies a category-determination secret key **153**. Then, the key information publishing unit **113** transmits to the data search server **300** the category-determination secret key **153** specified by the searcher among the plurality of the category-determination secret keys **153**.

At this time, the category secret key managing unit **310** of the data search server **300** receives the key-determination value **191** and the category-determination secret keys **153** transmitted by the key information publishing unit **113** of the data search terminal **100**. The category secret key managing unit **310** stores the key-determination value **191** and the category-determination secret keys **153** that have been received in the search-server storage unit **390**.

Then, the category secret key managing unit **310** generates a category-specific DB unit **391** for each of the received category-determination secret keys **153**. The category-specific DB unit **391** is a database for storing a system ciphertext **230** (see FIG. **7**) including an index tag **233** generated using the category-determination public key **143** which constitutes a key pair with the category-determination secret key **153**.

The category secret key managing unit **310** also generates a secret-key correspondence table **350** as shown in FIG. **9**. For example, when the category-specific DB unit **391** identified by "DB_1" is generated for the category-determination secret key **153** identified by "SK_1", the category secret key managing unit **310** associates "SK_1" with "DB_1" and sets them in the secret-key correspondence table **350**.

S**131** completes the setup process.

FIG. **11** is the flowchart illustrating the data registration process of the data registration terminal **200** in Embodiment 1.

Referring to FIG. **11**, the data registration process of the data registration terminal **200** in Embodiment 1 will be described.

A user who wishes to register search target data (to be referred to as a "registering person" hereinafter) activates the data registration request processing unit **220** of the data registration terminal **200**, and the data registration request processing unit **220** of the data registration terminal **200** executes the data registration process (S**210** to S**251**) described below.

In S**210**, using an input device, the registering person inputs to the registration information input unit **221** of the data registration terminal **200** data which the registering person wishes to register as search target data, a keyword associated with the data, and category information indicating a category to which the data belongs. That is, the registration information input unit **221** obtains from the

input device the data, the keyword, and the category information that are specified by the registering person.

After S**210**, processing proceeds to S**220**.

In S**220**, the data ciphertext generating unit **222** obtains the data public key **141** from the registration-terminal storage unit **290**, and encrypts the data input in S**210** using the obtained data public key **141**. The encrypted data will be hereinafter referred to as a "data ciphertext **231**".

After S**220**, processing proceeds to S**230**.

In S**230**, the keyword ciphertext generating unit **223** obtains the keyword public key **142** from the registration-terminal storage unit **290**, and encrypts the keyword input in S**210** using the obtained keyword public key **142**. The encrypted keyword will be hereinafter referred to as a "keyword ciphertext **232**".

After S**230**, processing proceeds to S**240**.

In S**240**, the index tag generating unit **224** refers to the public-key correspondence table **160** stored in the registration-terminal storage unit **290**.

Then, the index tag generating unit **224** selects a category-determination public key **143** associated with the category indicated by the category information input in S**210** from among the plurality of the category-determination public keys **143** indicated in the public-key correspondence table **160**, and obtains the selected category-determination public key **143** from the registration-terminal storage unit **290**.

After S**240**, processing proceeds to S**241**.

In S**241**, the index tag generating unit **224** obtains the key-determination value **191** from the registration-terminal storage unit **290**, and encrypts the key-determination value **191** using the category-determination public key **143** obtained in S**240**. The encrypted key-determination value **191** will be hereinafter referred to as an "index tag **233**".

After S**241**, processing proceeds to S**250**.

In S**250**, the data registration requesting unit **225** generates a system ciphertext **230** (see FIG. **7**) including the data ciphertext **231** generated in S**220**, the keyword ciphertext **232** generated in S**230**, and the index tag **233** generated in S**241**.

After S**250**, processing proceeds to S**251**.

In S**251**, the data registration requesting unit **225** transmits to the data search server **300** a registration request for requesting registration of the system ciphertext **230** generated in S**250**. The registration request is data including the system ciphertext **230**.

S**251** completes the data registration request process.

FIG. **12** is the flowchart illustrating the data registration process of the data search server **300** in Embodiment 1.

Referring to FIG. **12**, the data registration process of the data search server **300** in Embodiment 1 will be described.

In S**310**, the registration request receiving unit **321** receives the registration request for the system ciphertext **230** transmitted from the data registration terminal **200**.

After S**310**, processing proceeds to S**320**.

In S**320**, the category determining unit **340** determines whether or not there is any unselected category-determination secret key **153** which has not been selected in S**330** to be described later in the search-server storage unit **390**.

If there is any unselected category-determination secret key **153** (YES), processing proceeds to S**330**.

If there is no unselected category-determination secret key **153** (NO), processing proceeds to S**321**.

In S**330**, the category determining unit **340** selects one unselected category-determination secret key **153** from the search-server storage unit **390**, and obtains the selected category-determination secret key **153** from the search-server storage unit **390**.

After S**330**, processing proceeds to S**331**.

In S**331**, the category determining unit **340** obtains the index tag **233** from the system ciphertext **230** received in S**310**, and decrypts the obtained index tag **233** using the category-determination secret key **153** obtained in S**330**. A value obtained by decrypting the index tag **233** will be hereinafter referred to as a decrypted value of the index tag **233**.

After S**331**, processing proceeds to S**332**.

In S**332**, the category determining unit **340** compares the decrypted value of the index tag **233** obtained in S**331** with the key-determination value **191** stored in the search-server storage unit **390**.

If the decrypted value of the index tag **233** is equal to the key-determination value **191** (YES), processing proceeds to S**340**.

If the decrypted value of the index tag **233** is different from the key-determination value **191** (NO), processing returns to S**320**.

In S**340**, the data registering unit **322** refers to the secret-key correspondence table **350** (see FIG. **9**) stored in the search-server storage unit **390**, and selects a category-specific DB unit **391** associated with the category-determination secret key **153** selected in S**330**, from among the plurality of the category-specific DB units **391** indicated in the secret-key correspondence table **350**.

Then, the data registering unit **322** stores the system ciphertext **230** received in S**310** in the selected category-specific DB unit **391**.

S**340** completes the data registration process.

In S**321**, the data registering unit **322** stores the system ciphertext **230** received in S**310** in the unclassified DB unit **392**. That is, if the data ciphertext **231** of the system ciphertext **230** is not classified into any of the categories of the category-specific DB units **391**, the data registering unit **322** stores the system ciphertext **230** in the unclassified DB unit **392**. The unclassified DB unit **392** is generated in the data search server **300** in advance.

S**321** completes the data registration process.

Through the data registration request process shown in FIG. **11** and the data registration process shown in FIG. **12**, the system ciphertext **230** is stored in any one of the category-specific DB units **391** or the unclassified DB unit **392** of the data search server **300**.

FIG. **13** is the flowchart illustrating the data search request process of the data search terminal **100** in Embodiment 1.

Referring to FIG. **13**, the data search request process of the data search terminal **100** in Embodiment 1 will be described.

The searcher activates the search request processing unit **120** of the data search terminal **100**, and the search request processing unit **120** of the data search terminal **100** executes the data search request process (S**410** to S**441**) described below.

In S**410**, using the input device, the searcher inputs to the search keyword input unit **121** of the data search terminal **100** a search keyword and category information indicating a search target category. That is, the search keyword input unit **121** obtains from the input device the search keyword and the category information that are specified by the searcher.

After S**410**, processing proceeds to S**420**.

In S**420**, the search query generating unit **122** obtains the keyword secret key **152** from the search-terminal storage unit **190**, and encrypts the search keyword input in S**410** using the obtained keyword secret key **152**. The encrypted search keyword will be hereinafter referred to as a "search trapdoor **171**".

After S**420**, processing proceeds to S**421**.

In S**421**, the search query generating unit **122** refers to the public-key correspondence table **160** stored in the search-terminal storage unit **190**, and selects a category-determination public key **143** associated with the category indicated by the category information input in S**410**, from among the plurality of the category-determination public keys **143** indicated in the public-key correspondence table **160**.

After S**421**, processing proceeds to S**422**.

In S**422**, the search query generating unit **122** obtains the key-determination value **191** from the search-terminal storage unit **190**, and encrypts the obtained key-determination value **191** using the category-determination public key **143** selected in S**421**. The encrypted key-determination value **191** will be hereinafter referred to as an "index tag **172**".

After S**422**, processing proceeds to S**423**.

In S**423**, the search query generating unit **122** generates a search query **170** (see FIG. **5**) including the search trapdoor **171** generated in S**420** and the index tag **172** generated in S**422**.

After S**423**, processing proceeds to S**430**.

In S**430**, the search requesting unit **123** transmits the search query **170** generated in S**423** to the data search server **300**.

After S**430**, processing proceeds to S**431**.

In S**431**, the search requesting unit **123** receives a search result transmitted from the data search server **300**. The search result is data including a data ciphertext **231** corresponding to the search query **170** (in other words, "data ciphertext **231** that satisfies a search condition" or "data ciphertext **231** that has been found as a hit in the search process").

After S**431**, processing proceeds to S**440**.

In S**440**, the search result output unit **124** obtains the data secret key **151** from the search-terminal storage unit **190**, and decrypts the data ciphertext **231** included in the search result received in S**431** using the obtained data secret key **151**. By decrypting the data ciphertext **231**, data before being encrypted can be obtained.

After S**440**, processing proceeds to S**441**.

In S**441**, the search result output unit **124** outputs a search result including the data obtained in S**440**. For example, the search result output unit **124** displays the search result on a display.

S**441** completes the data search request process.

FIG. **14** is the flowchart illustrating the data search process of the data search server **300** in Embodiment 1.

Referring to FIG. **14**, the data search process of the data search server **300** in Embodiment 1 will be described.

In S**510**, the search request receiving unit **331** receives the search query **170** transmitted from the data search terminal **100**. The search query **170** is data including the search trapdoor **171** and the index tag **172** (see FIG. **5**).

After S**510**, processing proceeds to S**520**.

In S**520**, the category determining unit **340** determines whether or not there is any unselected category-determination secret key **153** which has not been selected in S**530** to be described later in the search-server storage unit **390**.

If there is any unselected category-determination secret key **153** (YES), processing proceeds to S**530**.

If there is no unselected category-determination secret key **153** (NO), processing proceeds to S**521**.

In S**530**, the category determining unit **340** selects one unselected category-determination secret key **153** from the search-server storage unit **390**, and obtains the selected category-determination secret key **153** from the search-server storage unit **390**.

After S**530**, processing proceeds to S**531**.

In S**531**, the category determining unit **340** obtains the index tag **172** from the search query **170** received in S**510**, and decrypts the obtained index tag **172** using the category-determination secret key **153** obtained in S**530**. A value obtained by decrypting the index tag **172** will be hereinafter referred to as a decrypted value of the index tag **172**.

After S**531**, processing proceeds to S**532**.

In S**532**, the category determining unit **340** compares the decrypted value of the index tag **172** obtained in S**531** with the key-determination value **191** stored in the search-server storage unit **390**.

If the decrypted value of the index tag **172** is equal to the key-determination value **191** (YES), processing proceeds to S**540**.

If the decrypted value of the index tag **172** is different from the key-determination value **191** (NO), processing returns to S**520**.

In S**540**, the data searching unit **332** refers to the secret-key correspondence table **350** (see FIG. **9**) stored in the search-server storage unit **390**, and selects, as a search target DB unit, a category-specific DB unit **391** associated with the category-determination secret key **153** selected in S**530**, from among the plurality of the category-specific DB units **391** indicated in the secret-key correspondence table **350**.

Then, the data searching unit **332** obtains the search trapdoor **171** from the search query **170** received in S**510**, and searches the search target category-specific DB unit **391** using the obtained search trapdoor **171**, in accordance with a search algorithm of a PEKS scheme.

For example, the data searching unit **332** performs a search as described below.

The data searching unit **332** selects a system ciphertext **230** one by one from the search target category-specific DB unit **391**, and obtains a keyword ciphertext **232** from the selected system ciphertext **230**.

Using the keyword ciphertext **232** and the search trapdoor **171** as input data, the data searching unit **332** executes the search algorithm (search program) of the PEKS scheme.

Based on the result of execution of the search algorithm, the data searching unit **332** determines whether the data keyword before being encrypted into the keyword ciphertext **232** matches the search keyword before being encrypted into the search trapdoor **171**. If the data keyword of the keyword ciphertext **232** matches the search keyword of the search trapdoor **171**, the data ciphertext **231** that is included in the system ciphertext **230** together with this keyword ciphertext **232** is the data ciphertext **231** that has been found as a hit in the search process.

After S**540**, processing proceeds to S**550**.

In S**521**, the data searching unit **332** obtains the search trapdoor **171** from the search query **170** received in S**510**, and searches the unclassified DB unit **392** using the obtained search trapdoor **171** in accordance with the search algorithm of the PEKS scheme. That is, the data searching unit **332** performs a search process on the unclassified DB unit **392** instead of the category-specific DB units **391**. The search method is the same as in S**540**.

After S**521**, processing proceeds to S**550**.

In S**550**, the search result transmitting unit **333** transmits to the data search terminal **100** a search result including the data ciphertext **231** that has been found as a hit in the search process in S**540** or S**521**.

S**550** completes the data search process.

Through the data search process shown in FIG. **14**, the data search server **300** can perform a search using the PEKS scheme on the category-specific DB unit **391** of the category

specified by the searcher (or the unclassified DB unit **392**). That is, the data search server **300** can perform a keyword search with the data, the search keyword and the search target category being kept secret. Furthermore, by performing a search on the category-specific DB unit **391** of the category specified by the searcher (or the unclassified DB unit **392**), the data search server **300** can reduce search time compared to when a search is performed on all the data ciphertexts **231**.

FIG. **15** is the flowchart illustrating the category registration request process of the data search terminal **100** in Embodiment 1.

Referring to FIG. **15**, the category registration request process of the data search terminal **100** in Embodiment 1 will be described.

In S**601**, using the input device, the searcher inputs to the category registration requesting unit **130** of the data search terminal **100** category information indicating a category into which the searcher wishes to classify a system ciphertext **230** that is unclassified. That is, the category registration requesting unit **130** obtains from the input device the category information specified by the searcher.

After S**601**, processing proceeds to S**602**.

In S**602**, the category registration requesting unit **130** refers to the public-key correspondence table **160** (see FIG. **4**) stored in the search-terminal storage unit **190**, and selects a category-determination secret key **153** associated with the category indicated in the category information input in S**601**, from among the plurality of the category-determination secret keys **153** indicated in the public-key correspondence table **160**.

After S**602**, processing proceeds to S**603**.

In S**603**, the category registration requesting unit **130** obtains from the search-terminal storage unit **190** the category-determination secret key **153** selected in S**602**, and transmits to the data search server **300** a category registration request including the obtained category-determination secret key **153**.

S**603** completes the category registration request process.

FIG. **16** is the flowchart illustrating the category registration process of the data search server **300** in Embodiment 1.

Referring to FIG. **16**, the category registration process of the data search server **300** in Embodiment 1 will be described.

In S**610**, the category secret key managing unit **310** receives the category registration request transmitted from the data search terminal **100**. The category registration request is data including the category-determination secret key **153**.

The category secret key managing unit **310** obtains the category-determination secret key **153** from the received category registration request, and stores the obtained category-determination secret key **153** in the search-server storage unit **390**.

After S**610**, processing proceeds to S**620**.

In S**620**, the category secret key managing unit **310** newly generates a category-specific DB unit **391**.

After S**620**, processing proceeds to S**630**.

In S**630**, the category secret key managing unit **310** associates the category-determination secret key **153** obtained in S**610** with the category-specific DB unit **391** generated in S**620**, and sets them in the secret-key correspondence table **350** (see FIG. **9**).

After S**630**, processing proceeds to S**640**.

In S**640**, the category secret key managing unit **310** determines whether or not there is any unselected system ciphertext **230** which has not been selected in S**641** to be described later in the unclassified DB unit **392**.

If there is any unselected system ciphertext **230** in the unclassified DB unit **392** (YES), processing proceeds to S**641**.

If there is no unselected system ciphertext **230** in the unclassified DB unit **392** (NO), the category registration process ends.

In S**641**, the category secret key managing unit **310** selects one unselected system ciphertext **230** from the unclassified DB unit **392**, and obtains the selected system ciphertext **230** from the unclassified DB unit **392**.

After S**641**, processing proceeds to S**642**.

In S**642**, the category secret key managing unit **310** obtains an index tag **233** from the system ciphertext **230** selected in S**641**, and decrypts the obtained index tag **233** using the category-determination secret key **153** obtained in S**610**. A value obtained by decrypting the index tag **233** will be hereinafter referred to as a decrypted value of the index tag **233**.

After S**642**, processing proceeds to S**643**.

In S**643**, the category secret key managing unit **310** compares the decrypted value of the index tag **233** obtained in S**642** with the key-determination value **191** stored in the search-server storage unit **390**.

If the decrypted value of the index tag **233** is equal to the key-determination value **191** (YES), processing proceeds to S**644**.

If the decrypted value of the index tag **233** is different from the key-determination value **191** (NO), processing returns to S**640**.

In S**644**, the category secret key managing unit **310** moves the system ciphertext **230** selected in S**641**, from the unclassified DB unit **392** to the category-specific DB unit **391** newly generated in S**620**.

After S**644**, processing returns to S**640**.

Through the category registration request process shown in FIG. **15** and the category registration process shown in FIG. **16**, a category-specific DB unit **391** for a new category is generated, and a system ciphertext **230** classified into the new category is stored in the generated category-specific DB unit **391**.

FIG. **17** is a diagram illustrating an example of hardware resources of the data search system **900** in Embodiment 1.

In FIG. **17**, each of the data search terminal **100**, the data registration terminal **200**, and the data search server **300** (an example of a computer, respectively) includes a CPU **901** (Central Processing Unit). The CPU **901** is connected via a bus **902** to hardware devices such as a ROM **903**, a RAM **904**, a communication board **905**, a display **911** (display device), a keyword **912**, a mouse **913**, a drive **914**, and a magnetic disk device **920**, and controls these hardware devices. The drive **914** is a device for reading from and writing to a storage medium such as an FD (Flexible Disk Drive), a CD (Compact Disc), or a DVD (Digital Versatile Disc).

The ROM **903**, the RAM **904**, the magnetic disk device **920**, and the drive **914** are examples of a storage device. The keyboard **912**, the mouse **913**, and the communication board **905** are examples of an input device. The display **911** and the communication board **905** are examples of an output device.

The communication board **905** is connected in a wired or wireless manner to a communication network such as a LAN (Local Area Network), the Internet, or a telephone line.

The magnetic disk device **920** stores an OS **921** (operating system), programs **922**, and files **923**.

The programs **922** include programs that execute functions described as "units" in the embodiments. The programs (e.g., a data search program, a data registration program, an information processing program) are read and executed by the CPU **901**. That is, each program causes the computer to function as each "unit", or causes the computer to execute a procedure or a method of each "unit".

The files **923** include various types of data (input, output, determination result, computation result, processing result, etc.) used in the "units" described in the embodiments.

In the embodiments, arrows included in the configuration diagrams and the flowcharts mainly denote inputs and outputs of data and signals.

The processes of the embodiments described with reference to the flowcharts or the like are executed using the hardware such as the CPU **901**, the storage device, the input device, and the output device.

In the embodiments, what is described as a "unit" may be a "circuit", "device" or "equipment", and may also be a "step", "procedure", or "process". That is, what is described as a "unit" may be implemented by firmware, software, hardware, or a combination of these.

The data search system **900** in Embodiment 1 has, for example, the following features.

(1) An index tag is added to each of a ciphertext (system ciphertext **230**) and a search query (see FIGS. **5** and **7**).

(2) By publishing a secret key (category-determination secret key **153**) to the data search server **300**, specific data corresponding to the secret key is separated from the whole.

(3) The index tag in the search query is decrypted with the secret key. Based on this result, the scope to be searched is limited (see FIG. **14**.).

(4) By combining the above (1) to (3), performing a search on the entire data can be avoided, so that a faster search can be performed.

The data search system **900** in Embodiment 1 can provide, for example, the following effects.

(1) There is an effect in that a faster search can be achieved in PEKS.

(2) There is an effect in that a faster search can be performed by targeting at specific data (e.g., data in a given category).

(3) There is an effect in that a searcher can adaptively increase categories for achieving a faster search (see FIGS. **15** and **16**).

(4) There is an effect in that by using a public-key encryption scheme with key-privacy, such as ElGamal encryption or Cramer-Shoup encryption, as public-key encryption used for creating an index tag, a faster search can be achieved with category information of each ciphertext being kept secret to the data search server **300**. There is also an effect in that by using a public-key encryption scheme without key-privacy, options for selecting a public-key encryption scheme can be increased.

(5) There is an effect in that with a configuration in which category-determination key pairs (see FIG. **3**) and index tags (see FIGS. **5** and **7**) are additionally provided (provided as add-ons), implementation can be achieved without greatly changing an existing PEKS. By this, there is an effect in that the cost of implementation can be reduced.

The data search system **900** in Embodiment 1 may be configured as described below.

(1) Each system ciphertext **230** may include a plurality of index tags **233**. In this case, the registering person specifies (inputs) a plurality of category information to the data registration terminal **200**. Then, the data registration terminal **200** generates an index tag **233** for each of the specified categories, and sets a plurality of generated index tags **233** in the system ciphertext **230**. The data search server **300** stores the system ciphertext **230** in a plurality of category-specific DB units **391** corresponding to the plurality of index tags **233** included in the system ciphertext **230**. With this arrangement, data covering a plurality of categories can be supported.

(2) In Embodiment 1, an example has been presented in which a constant (e.g., "1") is used as a plaintext (key-determination value **191**) of the index tag. Alternatively, a plaintext depending on search target data or a keyword may be used.

For example, a hash value of the keyword ciphertext **232** (see FIG. **7**) may be used as the plaintext of the index tag. With this arrangement, a correspondence is generated between the keyword ciphertext **232** and the index tag, so that a resistance against data exchange attacks on a communication path can be provided. In this case, the data search terminal **100**, the data registration terminal **200**, and the data search server **300** compute and use the hash value of the keyword ciphertext **232** instead of using the key-determination value **191**.

(3) A plurality of key-determination values **191** may be used to provide detailed classification categories. By providing detailed classification categories, a faster search can be achieved.

For example, the data search system **900** operates as described below.

The data search terminal **100** generates a key-determination-value correspondence table **192** as shown in FIG. **18**, and provides the generated key-determination-value correspondence table **192** to the data registration terminal **200** and the data search server **300**.

The user specifies a large category and a small category to the data search terminal **100** and the data registration terminal **200**, and the data search terminal **100** and the data registration terminal **200** use the key-determination values **191** corresponding to the large category and the small category.

The data search server **300** generates a category-specific DB unit **391** for each large category (for each category-determination secret key **153**), and stores system ciphertexts **230** according to small categories within each category-specific DB unit **391**. For example, within a category-specific DB unit **391**, the data search server **300** separately manages a system ciphertext **230** having "11" as a decrypted value of the index tag **233** and a system ciphertext **230** having "12" as a decrypted value of the index tag **233**.

FIG. **18** is a diagram illustrating the key-determination-value correspondence table **192** in Embodiment 1. As shown in FIG. **18**, the key-determination-value correspondence table **192** is data associating a large category, a small category, and a key-determination value **191**. Categories may be classified into three or more levels (e.g., large, middle, small).

(4) In Embodiment 1, the method for adaptively increasing categories (see FIGS. **15** and **16**) has been presented. Alternatively, categories may be adaptively reduced.

For example, the searcher operates the data search terminal **100** to transmit a category delete request to the data search server **300**. The category delete request is data specifying a category-determination secret key **153** of a category to be deleted. In accordance with the delete request, the data search server **300** deletes the category-determination secret key **153**, and takes out and moves system ciphertexts **230** from the category-specific DB unit **391**

corresponding to the category-determination secret key **153** to the unclassified DB unit **392**, and deletes the category-specific DB unit **391**.

(5) In Embodiment 1, an example has been presented in which a predetermined number of key pairs of the category-determination public keys **143** and the category-determination secret keys **153** are generated. Alternatively, a key pair of the category-determination public keys **143** and the category-determination secret keys **153** may be added as required.

For example, when the searcher wishes to add a category, the searcher inputs additional category information to the data search terminal **100**. In this case, based on the additional category information, the data search terminal **100** newly generates a key pair of a category-determination public key **143** and a category-determination secret key **153**, updates the public-key correspondence table **160**, and provides the category-determination public key **143**, the category-determination secret key **153**, and the public-key correspondence table **160** to the data registration terminal **200** and the data search server **300**, as in the setup process.

(6) In Embodiment 1, an example has been presented in which system ciphertexts **230** are classified according to categories related to the contents of data (data ciphertexts **231**) and keywords (keyword ciphertexts **232**) (e.g., "patent", "design"). Alternatively, system ciphertexts **230** may be classified according to other attributes of data (creation date, data size, etc.) With this arrangement, system ciphertexts **230** can be managed according to the attributes (types) of data, and a faster search can be achieved.

FIG. **19** is a diagram illustrating another example of the public-key correspondence table **160** in Embodiment 1.

For example, the data search terminal **100** generates a public-key correspondence table **160** as shown in FIG. **19**, and provides the public-key correspondence table **160** generated to the data registration terminal **200**. The data registration terminal **200** generates an index tag **233** of a system ciphertext **230** by using a category-determination public key **143** associated with a creation date of the system ciphertext **230** among a plurality of the category-determination public keys **143** indicated in the public-key correspondence table **160**. The searcher inputs to the data search terminal **100** a creation date of data the searcher wishes to obtain. Then, the data search terminal **100** generates an index tag **172** of a search query **170** by using a category-determination public key **143** associated with the input creation date of the data among the plurality of the category-determination public keys **143** indicated in the public-key correspondence table **160**.

(7) In place of the public-key encryption scheme (or PEKS), another encryption scheme (e.g., symmetric-key encryption scheme) may be employed. Alternatively, data and keywords that have not been encrypted may be registered as required.

In Embodiment 1, the data search system **900** as described below, for example, has been described.

A data search device (data search server **300**) includes a data storage unit, a key-determination information storage unit, a search condition input unit, a data group selecting unit, a data searching unit, and a search result output unit.

The data storage unit (storage device) is configured to store a plurality of data groups (category-specific DB units **391**), each data group including one or more pieces of data (system ciphertexts **230**), and a plurality of decryption keys (category-determination secret keys **153**) for decrypting encrypted information, by associating each of the plurality of the data groups with each of the plurality of the decryption keys.

The key-determination information storage unit (search-server storage unit **390**) is configured to store key-determination information (key-determination value **191**) for determining a decryption key.

The search condition input unit (search request receiving unit **331**) is configured to obtain a search condition (search trapdoor **171**) for searching for data, and obtain encrypted information (index tag **172**) generated by encrypting predetermined information (key-determination value **191**).

The data group selecting unit (category determining unit **340**) is configured to decrypt the encrypted information obtained by the search condition input unit by using each of the plurality of the decryption keys stored in the data storage unit. The data group selecting unit is configured to select a decryption key with which the encrypted information is decrypted to same information as the key-determination information, from among the plurality of the decryption keys. The data group selecting unit is configured to select as a search target group a data group associated with the decryption key selected, from among the plurality of the data groups stored in the data storage unit;

The data searching unit (data searching unit **332**) is configured to obtain as search result data a piece of data that satisfies the search condition obtained by the search condition input unit, from among the one or more pieces of data included in the search target group selected by the data group selecting unit.

The search result output unit (search result transmitting unit **333**) is configured to output the search result data obtained by the data searching unit.

The data search device further includes a new data input unit and a new data registering unit.

The new data input unit (registration request receiving unit **321**) is configured to obtain new data (data ciphertext **231**) and an encrypted tag (index tag **233**) generated by encrypting predetermined information (key-determination value **191**).

The new data registering unit (data registering unit **322**) is configured to add the new data obtained by the new data input unit to a registration target group which is selected from among the plurality of the data groups by the data group selecting unit.

The data group selecting unit is configured to decrypt the encrypted tag obtained by the new data input unit by using each of the plurality of the decryption keys. The data group selecting unit is configured to select a decryption key with which the encrypted tag is decrypted to the same information as the key-determination information, from among the plurality of the decryption keys. The data group selecting unit is configured to select as the registration target group a data group associated with the decryption key selected, from among the plurality of the data groups.

The data storage unit (storage device) is configured to further store an unclassified group (unclassified DB unit **392**) as a data group including a plurality of pieces of data and a plurality of encrypted tags generated by encrypting the predetermined information, each of the plurality of the pieces of data being associated with each of the plurality of the encrypted tags.

The data search device further includes an additional decryption key input unit and a data group registering unit.

The additional decryption key input unit (category secret key managing unit **310**) is configured to obtain a new decryption key (category-determination secret key **153**) as an additional decryption key.

The data group registering unit (category secret key managing unit **310**) is configured to decrypt the plurality of the encrypted tags included in the unclassified group by using the additional decryption key obtained by the additional decryption key input unit. The data group registering unit is configured to select an encrypted tag which is decrypted to the same information as the key-determination information, from among the plurality of the encrypted tags. The data group registering unit is configured to extract a piece of data associated with the encrypted tag selected, from among the plurality of the pieces of data included in the unclassified group, and generate an additional group including the piece of data extracted, as a new data group to be added to the plurality of the data groups. The data group registering unit is configured to store the additional group generated and the additional decryption key in the data storage unit by associating the additional group generated with the additional decryption key.

A data registration device (data registration terminal **200**) includes a data generating unit, a classification information input unit, an encrypted tag generating unit, and a data registration requesting unit.

The data generating unit (data ciphertext generating unit **222**) is configured to generate data (data ciphertext **231**).

The classification information input unit (registration information input unit **221**) is configured to obtain classification information indicating a classification of the data generated by the data generating unit.

The encrypted tag generating unit (index tag generating unit **224**) is configured to generate an encrypted tag (index tag **233**) by encrypting predetermined information (key-determination value **191**) based on the classification information obtained by the classification information input unit.

The data registration requesting unit (data registration requesting unit **225**) is configured to transmit to a data search device (data search server **300**) the data generating unit and the encrypted tag generated by encrypted tag generating unit. The data registration requesting unit thereby causes the data search device to execute a process of adding the data to a data group of the classification indicated by the classification information, as search target data.

The data registration device further includes an encryption key storage unit (registration-terminal storage unit **290**) configured to store a plurality of encryption keys (category-determination public keys **143**) and a plurality of pieces of classification information (category information) by associating each the plurality of the encryption keys with each of the plurality of the pieces of classification information.

The encrypted tag generating unit is configured to select an encryption key associated with same classification information as the classification information obtained by the classification information input unit, from among the plurality of the encryption keys stored in the encryption key storage unit, and generate the encrypted tag by encrypting the predetermined information by using the encryption key selected.

An information processing device (data search terminal **100**) includes a search condition input unit, an encrypted tag generating unit, and a data search requesting unit. The search condition input unit (search keyword input unit **121**) is configured to obtain a search condition (search keyword) for searching for data (data ciphertext **231**), and obtain classification information (category information) indicating a classification of the data.

The encrypted tag generating unit (search query generating unit **122**) is configured to generate an encrypted tag (index tag **172**) by encrypting predetermined information (key-determination value **191**) based on the classification information obtained by the search condition input unit.

The data search requesting unit (search requesting unit **123**) is configured to transmit to a data search device (data search server **300**) information of the search condition (search trapdoor **171**) obtained by the search condition input unit and the encrypted tag generated by the encrypted tag generating unit. The data search requesting unit is configured to receive as search result data from the data search device a piece of data that satisfies the search condition, from among pieces of data included in a data group of the classification indicated by the classification information.

The information processing device further includes an encryption key storage unit (search-terminal storage unit **190**) configured to store a plurality of encryption keys (category-determination public keys **143**) and a plurality of pieces of classification information by associating each of the plurality of the encryption keys with each of the plurality of the pieces of classification information.

The encrypted tag generating unit is configured to select an encryption key associated with same classification information as the classification information obtained by the search condition input unit, from among the plurality of the encryption keys stored in the encryption key storage unit, and generate the encrypted tag by encrypting the predetermined information by using the encryption key selected.

Embodiment 2

An embodiment in which ID-based encryption (IBE: Identity-Based Encryption) is employed in place of public-key encryption will be described.

ID-based encryption is an encryption scheme in which an identifier (ID), such as a user name, an IP address, or a mail address, is used as a public key.

Features that are different from Embodiment 1 will be mainly described hereinafter. Features not described are substantially the same as those in Embodiment 1.

A configuration of the data search system **900**, and functional configurations of the data search terminal **100**, the data registration terminal **200**, and the data search server **300** are substantially the same as those in Embodiment 1 (see FIGS. **1**, **2**, **6**, and **8**).

However, the data search system **900** differs from that in Embodiment 1 in the following points.

Since the data search system **900** employs ID-based encryption in place of public-key encryption, the public-key correspondence table **160** (see FIG. **4**) described in Embodiment 1 is not needed. For this reason, the public-key correspondence table generating unit **112** of the data search terminal **100** is also not needed. Processes will be described in detail later.

FIG. **20** is a diagram illustrating a system public key **140** and a system secret key **150** in Embodiment 2.

Referring to FIG. **20**, the system public key **140** and the system secret key **150** in Embodiment 2 will be described.

The system public key **140** has one IBE master public key **144** in place of a plurality of the category-determination public keys **143** described in Embodiment 1 (see FIG. **3**). The IBE master public key **144** is a master public key of ID-based encryption.

The system secret key **150** has one IBE master secret key **154** in place of a plurality of the category-determination secret keys **153** described in Embodiment 1 (see FIG. **3**). The IBE master secret key **154** is a master secret key of ID-based encryption.

FIG. **21** is a flowchart illustrating a setup process of the data search terminal **100** in Embodiment 2.

Referring to FIG. **21**, the setup process of the data search terminal **100** in Embodiment 2 will be described.

S**110**B to S**131**B to be described below are steps corresponding to S**110** to S**131** described in Embodiment 1 (see FIG. **10**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

In S**110**B, the system key generating unit **111** generates a system public key **140** and a system secret key **150**.

As shown in FIG. **20**, the system public key **140** includes an IBE master public key **144**, and the system secret key **150** includes an IBE master secret key **154**.

The system key generating unit **111** executes a master key generation algorithm of an ID-based encryption scheme, and generates a key pair of the IBE master public key **144** and the IBE master secret key **154**.

For example, the system key generating unit **111** uses an ID-based encryption scheme with anonymity, such as Boneh-Franklin ID-based encryption (BF-IBE) (see Non-Patent Literature 4) or Boyen-Waters ID-based encryption (BW-IBE) (see Non-Patent Literature 5). Anonymity refers to the property that the ID used as a public key cannot be known by looking at a ciphertext (see Non-Patent Literature 6).

Note that the system key generating unit **111** may use an ID-based encryption scheme without anonymity (e.g., Boneh-Boyen ID-based encryption (BB-IBE)).

After S**110**B, processing proceeds to S**130**B.

In S**130**B, as in S**130** in Embodiment 1, the key information publishing unit **113** publishes the system public key **140**, a key-determination value **191**, and a public parameter of ID-based encryption to the data registration terminal **200**. Note that a public-key correspondence table **160** is not needed.

After S**130**B, processing proceeds to S**131**B.

In S**131**B, using the IBE master secret key **154** and category information, the key information publishing unit **113** executes a user secret key generation algorithm of ID-based encryption, and generates category-specific user secret keys. The category information is specified (input) to the data search terminal **100** by a user.

As in S**131** in Embodiment 1, the key information publishing unit **113** registers with the data search server **300** the category-specific user secret keys (in place of the category-determination secret keys **153**), the key-determination value **191**, and the public parameter of ID-based encryption. The data search server **300** generates a secret-key correspondence table **350** associating each category-specific user secret key with a category-specific DB unit **391**.

S**131**B completes the setup process.

FIG. **22** is a flowchart illustrating a data registration request process of the data registration terminal **200** in Embodiment 2.

Referring to FIG. **22**, the data registration request process of the data registration terminal **200** in Embodiment 2 will be described.

S**210** to S**251** to be described below are steps corresponding to S**210** to S**251** described in Embodiment 1 (see FIG. **11**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

S**210** to S**230** are the same as in Embodiment 1. After S**230**, processing proceeds to S**241**B.

In S**241**B, using the IBE master public key **144** and the category information, the index tag generating unit **224** executes an encryption algorithm of ID-based encryption, and generates an index tag **233** by encrypting the key-determination value **191**. That is, using the IBE master public key **144**, the index tag generating unit **224** encrypts the key-determination value **191**. The category information is used as a parameter.

After S**241**B, processing proceeds to S**250**.

S**250** and S**251** are the same as in Embodiment 1. S**251** completes the data registration request process.

FIG. **23** is a flowchart illustrating a data registration process of the data search server **300** in Embodiment 2.

Referring to FIG. **23**, the data registration process of the data search server **300** in Embodiment 2 will be described.

S**310** to S**340**B to be described below are steps corresponding to S**310** to S**340** described in Embodiment 1 (see FIG. **12**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

In S**310**, the registration request receiving unit **321** receives a registration request for a system ciphertext **230** from the data registration terminal **200**.

After S**310**, processing proceeds to S**320**B.

In S**320**B, the category determining unit **340** determines whether or not there is any unselected category-specific user secret key which has not been selected in S**330**B to be described later in the search-server storage unit **390**.

If there is any unselected category-specific user secret key (YES), processing proceeds to S**330**B.

If there is no unselected category-specific user secret key (NO), processing proceeds to S**321**. In S**321**, the data registering unit **322** stores the system ciphertext **230** in the unclassified DB unit **392**.

In S**330**B, the category determining unit **340** selects one unselected category-specific user secret key from the search-server storage unit **390**.

After S**330**B, processing proceeds to S**331**B.

In S**331**B, using the category-specific user secret key selected in S**330**B, the category determining unit **340** decrypts the index tag **233** included in the system ciphertext **230**.

After S**331**B, processing proceeds to S**332**.

In S**332**, the category determining unit **340** compares the decrypted value of the index tag **233** obtained in S**331**B with the key-determination value **191**.

If the decrypted value of the index tag **233** is equal to the key-determination value **191** (YES), processing proceeds to S**340**B.

If the decrypted value of the index tag **233** is different from the key-determination value **191** (NO), processing returns to S**320**B.

In S**340**B, the data registering unit **322** stores the system ciphertext **230** in the category-specific DB unit **391** corresponding to the category-specific user secret key selected in S**330**B.

S**340**B completes the data registration process.

FIG. **24** is a flowchart illustrating a data search request process of the data search terminal **100** in Embodiment 2.

Referring to FIG. **24**, the data search request process of the data search terminal **100** in Embodiment 2 will be described.

S**410** to S**441** to be described below are steps corresponding to S**410** to S**441** described in Embodiment 1 (see FIG. **13**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

S410 and S420 are the same as in Embodiment 1. After S420, processing proceeds to S422B.

In S422B, using the IBE master public key **144** and the category information, the search query generating unit **122** executes an encryption algorithm of ID-based encryption, and generates an index tag **172** by encrypting the key-determination value **191**. That is, using the IBE master public key **144**, the search query generating unit **122** encrypts the key-determination value **191**. The category information is used as a parameter.

After S422B, processing proceeds to S423.

S423 to S441 are the same as in Embodiment 1. S441 completes the data search request process.

FIG. **25** is a flowchart illustrating a data search process of the data search server **300** in Embodiment 2.

Referring to FIG. **25**, the data search process of the data search server **300** in Embodiment 2 will be described.

S510 to S550 to be described below are steps corresponding to S510 to S550 described in Embodiment 1 (see FIG. **14**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

In S510, the search request receiving unit **331** receives a search query **170** including a search trapdoor **171** and an index tag **172** from the data search terminal **100**.

After S510, processing proceeds to S520B.

In S520B, the category determining unit **340** determines whether or not there is any unselected category-specific user secret key which has not been selected in S530B to be described later in the search-server storage unit **390**.

If there is any unselected category-specific user secret key (YES), processing proceeds to S530B.

If there is no unselected category-specific user secret key (NO), processing proceeds to S521. In S521, using the search trapdoor **171**, the data searching unit **332** searches the unclassified DB unit **392** in accordance with a search algorithm of a PEKS scheme.

In S530B, the category determining unit **340** selects one unselected category-specific user secret key from the search-server storage unit **390**.

After S530B, processing proceeds to S531B.

In S531B, using the category-specific user secret key selected in S530B, the category determining unit **340** decrypts the index tag **172**.

After S531B, processing proceeds to S532.

In S532, the category determining unit **340** compares the decrypted value of the index tag **172** obtained in S531B with the key-determination value **191**.

If the decrypted value of the index tag **172** is equal to the key-determination value **191** (YES), processing proceeds to S540B.

If the decrypted value of the index tag **172** is different from the key-determination value **191** (NO), processing returns to S520B.

In S540B, using the search trapdoor **171**, the data searching unit **332** searches the category-specific DB unit **391** corresponding to the category-specific user secret key selected in S530B, in accordance with a search algorithm of a searchable encryption scheme.

After S540B, processing proceeds to S550.

In S550, the search result transmitting unit **333** transmits to the data search terminal **100** a search result including the data ciphertext **231** that has been found as a hit in S540B or S521.

S550 completes the data search process.

FIG. **26** is a flowchart illustrating a category registration request process of the data search terminal **100** in Embodiment 2.

Referring to FIG. **26**, the category registration request process of the data search terminal **100** in Embodiment 2 will be described.

S601 to S603B to be described below are steps corresponding to S601 to S603 described in Embodiment 1 (see FIG. **15**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

In S601, the category registration requesting unit **130** obtains category information specified by the searcher.

After S601, processing proceeds to S602B.

In S602B, using the IBE master secret key **154** and the category information, the category registration requesting unit **130** executes a user secret key generation algorithm of ID-based encryption, and generates a category-specific user secret key.

After S602B, processing proceeds to S603B.

In S603B, the category registration requesting unit **130** transmits to the data search server **300** a category registration request including the category-specific user secret key generated in S602B.

S603B completes the category registration request process.

FIG. **27** is a flowchart illustrating a category registration process of the data search server **300** in Embodiment 2.

Referring to FIG. **27**, the category registration process of the data search server **300** in Embodiment 2 will be described.

S610B to S644 to be described below are steps corresponding to S610 to S644 described in Embodiment 1 (see FIG. **16**). "B" will be appended as a suffix to a step that is partially different from Embodiment 1.

In S610B, the category secret key managing unit **310** receives the category registration request including the category-specific user secret key from the data search terminal **100**.

After S610B, processing proceeds to S620.

In S620, the category secret key managing unit **310** newly generates a category-specific DB unit **391**.

After S620, processing proceeds to S630B.

In S630B, the category secret key managing unit **310** sets in the secret-key correspondence table **350** a correspondence relation between the category-specific user secret key and the category-specific DB unit **391** newly generated.

After S630B, processing proceeds to S640.

In S640, the category secret key managing unit **310** determines whether or not there is any unselected system ciphertext **230** which has not been selected in S641 to be described later.

If there is any unselected system ciphertext **230** (YES), processing proceeds to S641.

If there is no unselected system ciphertext **230** (NO), the category registration process ends.

In S641, the category secret key managing unit **310** selects one unselected system ciphertext **230** from the registration-terminal storage unit **290**.

After S641, processing proceeds to S642B.

In S642B, using the category-specific user secret key, the category secret key managing unit **310** decrypts the index tag **233**.

After S642B, processing proceeds to S643.

In S643, the category secret key managing unit **310** compares the decrypted value of the index tag **233** obtained in S642B with the key-determination value **191**.

If the decrypted value of the index tag **233** is equal to the key-determination value **191** (YES), processing proceeds to S644.

If the decrypted value of the index tag **233** is different from the key-determination value **191** (NO), processing returns to S**640**.

In S**644**, the category secret key managing unit **310** moves the system ciphertext **230** selected in S**641** from the unclassified DB unit **392** to the category-specific DB unit **391** newly generated.

After S**644**, processing returns to S**640**.

In Embodiment 2, a public-key correspondence table **160** may be used as in Embodiment 1. In this case, the data search terminal **100** and the data registration terminal **200** operate as described below.

FIG. **28** is a diagram illustrating a public-key correspondence table **160** in Embodiment 2. As shown in FIG. **28**, the public-key correspondence table **160** is data associating each ID used as a category-determination public key with a category.

In place of generating a category-specific user public key using category information, the data search terminal **100** and the data registration terminal **200** generate a category-specific user public key using an ID corresponding to a category indicated in category information, among a plurality of IDs indicated in the public-key correspondence table **160**.

The data search system **900** in Embodiment 2 can provide, for example, the following effects.

(1) Effects that are substantially the same as those of Embodiment 1 can be obtained. In particular, a faster search can be achieved in PEKS. By using ID-based encryption with anonymity, category information of each ciphertext can be kept secret.

(2) Since a public-key correspondence table is not needed, the data registration terminal **200** can immediately generate an index tag **233** without referring to a public-key correspondence table. Note that a public-key correspondence table may be used.

(3) By using the IBE master public key **144** and the IBE master secret key **154**, an increase or decrease in the number of categories can be immediately supported.

Embodiment 3

An embodiment in which functional encryption (FE) is employed in place of ID-based encryption will be described.

Functional encryption is an encryption scheme in which a parameter x is used as a public key and a parameter y is used for generating a user, secret key. If the parameter x and the parameter y satisfy a predetermined relation R(x, y), then a ciphertext can be decrypted.

There are various types of the parameter x, the parameter y, and the relation R(x, y). For example, it is generally the case with functional encryption with attribute hiding that x and y are numerical vectors and the relation R is that the inner-product value of x and y is 0. These types of x, y, and R(x, y) are called inner-product predicates. For example, if x=(1, 34, 5) and y=(−29, 1, −1), then the inner-product value of x and y is 0, so that these x and y satisfy the relation R(x, y).

Attribute hiding refers to the property that the attribute used for encryption cannot be known by looking at a ciphertext (refer to Non-Patent Literature 8). Katz-Sahai-Waters inner-product predicate encryption (KSW-IPE) (see Non-Patent Literature 7) and Okamoto-Takashima inner-product predicate encryption (OT-IPE) (see Non-Patent Literature 8) are examples of a functional encryption scheme with attribute hiding. Sahai-Waters fuzzy ID-based encryption (SW-FIDE) is an example of functional encryption without attribute hiding.

Features that are different from those in Embodiments 1 and 2 will be mainly described. Features not described are substantially the same as those in Embodiment 1 or 2.

A configuration of the data search system **900** and functional configurations of the data search terminal **100**, the data registration terminal **200**, and the data search server **300** are substantially the same as those in Embodiment 1 (see FIGS. **1**, **2**, **6**, and **8**).

However, the data search system **900** differs from that in Embodiments 1 and 2 in the following points.

Since the data search system **900** employs functional encryption, a public-key correspondence table **160** is not needed as in the case of employing ID-based encryption (see Embodiment 2). For this reason, the public-key correspondence table generating unit **112** of the data search terminal **100** is also not needed. However, as in Embodiment 2 (see FIG. **28**), a public-key correspondence table **160** associating a parameter x (in place of an ID) with a category may be used.

FIG. **29** is a diagram illustrating a system public key **140** and a system secret key **150** in Embodiment 3.

Referring to FIG. **29**, the system public key **140** and the system secret key **150** in Embodiment 3 will be described.

The system public key **140** has one FE master public key **145** in place of a plurality of the category-determination public keys **143** described in Embodiment 1 (see FIG. **3**). The FE master public key **145** is a master public key of functional encryption.

The system secret key **150** has one FE master secret key **155** in place of a plurality of the category-determination secret keys **153** described in Embodiment 1 (see FIG. **3**). The FE master secret key **155** is a master secret key of functional encryption.

A setup process of the data search terminal **100** is substantially the same as that in Embodiment 2 (see FIG. **21**).

However, the system key generating unit **111** generates a system public key **140** including a master public key of functional encryption in place of the IBE master public key **144**, and generates a system secret key **150** including a master secret key of functional encryption in place of the IBE master secret key **154** (S**110**B).

A data registration request process of the data registration terminal **200** is substantially the same as that in Embodiment 2 (see FIG. **22**).

However, the index tag generating unit **224** generates an index tag **233** by encrypting the key-determination value **191** using the master public key of functional encryption in place of the IBE master public key **144** (S**241**B).

For example, the index tag generating unit **224** generates a user public key by setting category information (category name) in "CN" of a master public key "vector x (CN, 1)". Using the generated user public key, the index tag generating unit **224** encrypts the key-determination value **191** to generate the index tag **233**. That is, the index tag generating unit **224** generates the index tag **233** using as the public key a parameter x including the category information.

The registering person may specify a category using a complex condition taking advantage of characteristics of functional encryption. For example, it is known that an AND condition or an OR condition can be specified using inner-product predicate encryption. It is also known that a NOT condition can be specified using functional encryption with-

out attribute hiding. The index tag generating unit **224** uses a vector x formatted according to a search condition as a public key.

A data registration process of the data search server **300** is substantially the same as that in Embodiment 2 (see FIG. **23**).

However, each category-specific user secret key is a user secret key of functional encryption instead of ID-based encryption.

A data search request process of the data search terminal **100** is substantially the same as that in Embodiment 2 (see FIG. **24**).

However, like the index tag generating unit **224** described above, the search query generating unit **122** executes an encryption algorithm of a functional encryption scheme using the master public key of functional encryption in place of the IBE master public key **144**, and encrypts the key-determination value **191** to generate an index tag **172** (S**422**B).

A data search process of the data search server **300** is substantially the same as that in Embodiment 2 (see FIG. **25**).

However, each category-specific user secret key is a user secret key of functional encryption instead of ID-based encryption.

A category registration request process of the data search terminal **100** is substantially the same as that in Embodiment 2 (see FIG. **26**).

However, the category registration requesting unit **130** generates a category-specific user secret key using the master secret key of functional encryption in place of the IBE master secret key **154** (S**602**B).

For example, the category registration requesting unit **130** generates a category-specific user secret key by executing a user secret key generation algorithm of a functional encryption scheme using the master secret key of functional encryption and a vector y (−1, CN) as input, where CN is category information (category name). That is, the index tag generating unit **224** generates the category-specific user secret key by using a parameter y including the category information.

The searcher may specify a category with a complex condition taking advantage of characteristics of functional encryption. For example, it is known that an AND condition or an OR condition can be specified using inner-product predicate encryption. It is also known that a NOT condition can be specified using functional encryption without attribute hiding. In this case, the category registration requesting unit **130** uses a vector y formatted according to a condition.

A category registration process of the data search server **300** is substantially the same as that in Embodiment 2 (see FIG. **27**).

However, each category-specific user secret key is a user secret key of functional encryption instead of ID-based encryption.

The data search system **900** in Embodiment 3 can provide, for example, the following effects.

(1) Effects that are substantially the same as those of Embodiments 1 and 2 can be obtained. In particular, a faster search can be achieved in PEKS. By employing functional encryption with attribute hiding, category information of each ciphertext can be kept secret.

(2) Categories can be specified with more flexible conditions (AND condition, OR condition, NOT condition, etc.) compared to conditions for categories (ID match) when ID-based encryption is employed.

LIST OF REFERENCE SIGNS

100: data search terminal; **110**: setup processing unit; **111**: system key generating unit; **112**: public-key correspondence table generating unit; **113**: key information publishing unit; **120**: search request processing unit; **121**: search keyword input unit; **122**: search query generating unit; **123**: search requesting unit; **124**: search result output unit; **130**: category registration requesting unit; **140**: system public key; **141**: data public key; **142**: keyword public key; **143**: category-determination public key; **144**: IBE master public key; **150**: system secret key; **151**: data secret key; **152**: keyword secret key; **153**: category-determination secret key; **154**: IBE master secret key; **160**, **161**: public-key correspondence table; **170**: search query; **171**: search trapdoor; **172**: index tag; **190**: search-terminal storage unit; **191**: key-determination value; **192**: key-determination-value correspondence table; **199**: search result; **200**: data registration terminal; **210**: public information acquisition unit; **220**: data registration request processing unit; **221**: registration information input unit; **222**: data ciphertext generating unit; **223**: keyword ciphertext generating unit; **224**: index tag generating unit; **225**: data registration requesting unit; **230**: system ciphertext; **231**: data ciphertext; **232**: keyword ciphertext; **233**: index tag; **290**: registration-terminal storage unit; **300**: data search server; **310**: category secret key managing unit; **320**: data registration processing unit; **321**: registration request receiving unit; **322**: data registering unit; **330**: data search processing unit; **331**: search request receiving unit; **332**: data searching unit; **333**: search result transmitting unit; **340**: category determining unit; **350**: secret-key correspondence table; **390**: search-server storage unit; **391**: category-specific DB unit; **392**: unclassified DB unit; **900**: data search system; **901**: CPU; **902**: bus; **903**: ROM; **904**: RAM; **905**: communication board; **909**: network; **911**: display; **912**: keyboard; **913**: mouse; **914**: drive; **920**: magnetic disk device; **921**: OS; **922**: programs; **923**: files

The invention claimed is:

1. A data search device comprising:

a data storage unit configured to store a plurality of data groups into which pieces of search target data are classified and a plurality of decryption keys for decrypting encrypted identifiers of the data groups, by associating each of the plurality of the data groups with each of the plurality of the decryption keys;

a key-determination information storage unit configured to store key-determination information which is a value for determining a decryption key;

a search condition input unit configured to obtain a search condition which is a condition for searching for data, and obtain encrypted information generated by encrypting an identifier of a data group to be searched;

a data group selecting unit configured to

decrypt the encrypted information obtained by the search condition input unit by using one or more of the plurality of the decryption keys stored in the data storage unit, thereby generating one or more corresponding decryption results,

identify a decryption key of the plurality of the decryption keys that corresponds to a matched decryption result among the one or more corresponding decryption results, the matched decryption result being the same as the key-determination information, and

select as a search target group a data group associated with the identified decryption key, from among the plurality of the data groups stored in the data storage unit;

a data searching unit configured to obtain as search result data a piece of data that satisfies the search condition obtained by the search condition input unit, from among pieces of data included in the search target group selected by the data group selecting unit; and

a search result output unit configured to output the search result data obtained by the data searching unit.

2. The data search device according to claim **1**, further comprising:

a new data input unit configured to obtain new data and an encrypted tag generated by encrypting an identifier of a data group; and

a new data registering unit configured to add the new data obtained by the new data input unit to a registration target group which is selected from among the plurality of the data groups by the data group selecting unit,

wherein the data group selecting unit is configured to decrypt the encrypted tag obtained by the new data input unit by using one or more of the plurality of the decryption keys, identify another decryption key of the plurality of the decryption keys that corresponds to a decryption result which is the same as the key-determination information, and select as the registration target group a data group associated with the another identified decryption key, from among the plurality of the data groups.

3. The data search device according to claim **1**,

wherein the data storage unit is configured to further store an unclassified group as a data group including a plurality of pieces of data and a plurality of encrypted tags generated by encrypting the identifiers of the data groups, each of the plurality of the pieces of data being associated with each of the plurality of the encrypted tags,

the data search device further comprising:

an additional decryption key input unit configured to obtain a new decryption key as an additional decryption key; and

a data group registering unit configured to decrypt the plurality of the encrypted tags included in the unclassified group by using the additional decryption key obtained by the additional decryption key input unit, select an encrypted tag of the plurality of the encrypted tags that generates a decryption result which is the same as the key-determination information, extract a piece of data associated with the selected encrypted tag, from among the plurality of the pieces of data included in the unclassified group, generate an additional group including the piece of data extracted, as a new data group to be added to the plurality of the data groups, and store the additional group generated and the additional decryption key in the data storage unit by associating the additional group generated with the additional decryption key.

4. A data search method that is executed using a data search device,

the data search device including a data storage unit, a key-determination information storage unit, a search condition input unit, a data group selecting unit, a data searching unit, and a search result output unit,

the data storage unit being configured to store a plurality of data groups into which pieces of search target data are classified and a plurality of decryption keys for decrypting encrypted identifiers of the data groups, by associating each of the plurality of the data groups with each of the plurality of the decryption keys,

the key-determination information storage unit being configured to store key-determination information which is a value for determining a decryption key,

the data search method comprising:

obtaining a search condition which is a condition for searching for data, and obtaining encrypted information generated by encrypting an identifier of a data group to be searched, by the search condition input unit;

decrypting the encrypted information obtained by the search condition input unit by using one or more of the plurality of the decryption keys stored in the data storage unit, thereby generating one or more corresponding decryption results;

identifying a decryption key of the plurality of the decryption keys that corresponds to a matched decryption result among the one or more corresponding decryption results, the matched decryption result being the same as the key-determination information;

selecting as a search target group a data group associated with the identified decryption key, from among the plurality of the data groups stored in the data storage unit, by the data group selecting unit;

obtaining as search result data, by the data searching unit, a piece of data that satisfies the search condition obtained by the search condition input unit, from among pieces of data included in the search target group selected by the data group selecting unit; and

outputting, by the search result output unit, the search result data obtained by the data searching unit.

5. A non-transitory computer readable medium storing a data search program, which uses a data storage unit and a key-determination information storage unit,

the data storage unit being configured to store a plurality of data groups into which pieces of search target data are classified and a plurality of decryption keys for decrypting encrypted identifiers of the data groups, by associating each of the plurality of the data groups with each of the plurality of the decryption keys,

the key-determination information storage unit being configured to store key-determination information which is a value for determining a decryption key,

the data search program causing a computer to execute processes comprising:

a search condition input process of obtaining a search condition which is a condition for searching for data, and obtaining encrypted information generated by encrypting an identifier of a data group to be searched;

a data group selecting process including

decrypting the encrypted information obtained by the search condition input process by using one or more of the plurality of the decryption keys stored in the data storage unit,

identifying a decryption key of the plurality of the decryption keys that corresponds to a matched decryption result among the one or more corresponding decryption results, the matched decryption result being the same as the key-determination information, and

selecting as a search target group a data group associated with the identified decryption key, from among the plurality of the data groups stored in the data storage unit;

a data searching process of obtaining as search result data a piece of data that satisfies the search condition obtained by the search condition input process, from among pieces of data included in the search target group selected by the data group selecting process; and

a search result output process of outputting the search result data obtained by the data searching process.

6. A data registration device comprising:

a data generating unit configured to generate data;

a classification information input unit configured to obtain classification information indicating a classification of the data generated by the data generating unit;

an encrypted tag generating unit configured to generate an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the classification information input unit, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

a data registration requesting unit configured to transmit to the data search device the data generated by the data generating unit with the encrypted tag generated by encrypted tag generating unit, thereby causing the data search device to execute a process of adding the data to the data group of the classification indicated by the classification information, as search target data.

7. The data registration device according to claim **6**, further comprising:

an encryption key storage unit configured to store a plurality of encryption keys and a plurality of pieces of classification information by associating each of the plurality of the encryption keys with each of the plurality of the pieces of classification information,

wherein the encrypted tag generating unit is configured to select an encryption key associated with same classification information as the classification information obtained by the classification information input unit, from among the plurality of the encryption keys stored in the encryption key storage unit, and generate the encrypted tag by using the encryption key selected.

8. The data registration device according to claim **6**,

wherein the encrypted tag generating unit is configured to generate the encrypted tag in accordance with an ID-based encryption scheme using an ID based on the classification information.

9. The data registration device according to claim **6**,

wherein the encrypted tag generating unit is configured to generate the encrypted tag in accordance with a functional encryption scheme using a vector including the classification information.

10. A data registration method that is executed using a data registration device including a data generating unit, a classification information input unit, an encrypted tag generating unit, and a data registration requesting unit, the data registration method comprising:

generating data, by the data generating unit;

obtaining, by the classification information input unit, classification information indicating a classification of the data generated by the data generating unit;

generating, by the encrypted tag generating unit, an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the classification information input unit, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

transmitting, by the data registration requesting unit, the data generated by the data generating unit with the encrypted tag generated by the encrypted tag generating unit to the data search device, thereby causing the data search device to execute a process of adding the data to the data group of the classification indicated by the classification information, as search target data.

11. A non-transitory computer readable medium storing a data registration program for causing a computer to execute processes comprising:

a data generating process of generating data;

a classification information input process of obtaining classification information indicating a classification of the data generated by the data generating process;

an encrypted tag generating process of generating an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the classification information input process, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

a data registration requesting process of transmitting to the data search device the data generated by the data generating process with the encrypted tag generated by the encrypted tag generating process, thereby causing the data search device to execute a process of adding the data to the data group of the classification indicated by the classification information, as search target data.

12. An information processing device comprising:

a search condition input unit configured to obtain a search condition for searching for data, and obtain classification information indicating a classification of the data;

an encrypted tag generating unit configured to generate an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the search condition input unit, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

a data search requesting unit configured to transmit to the data search device information of the search condition obtained by the search condition input unit with the encrypted tag generated by the encrypted tag generating unit, and receive as search result data from the data search device a piece of data that satisfies the search condition, from among pieces of data included in the data group of the classification indicated by the classification information.

13. The information processing device according to claim **12**, further comprising:

an encryption key storage unit configured to store a plurality of encryption keys and a plurality of pieces of classification information by associating each of the plurality of the encryption keys with each of the plurality of the pieces of classification information,

wherein the encrypted tag generating unit is configured to select an encryption key associated with same classi-

fication information as the classification information obtained by the search condition input unit, from among the plurality of the encryption keys stored in the encryption key storage unit, and generate the encrypted tag by using the encryption key selected.

14. The information processing device according to claim **12**,

wherein the encrypted tag generating unit is configured to generate the encrypted tag in accordance with an ID-based encryption scheme using an ID based on the classification information.

15. The information processing device according to claim **12**,

wherein the encrypted tag generating unit is configured to generate the encrypted tag in accordance with a functional encryption scheme using a vector including the classification information.

16. A data search method that is executed using an information processing device including a search condition input unit, an encrypted tag generating unit, and a data search requesting unit, the data search method comprising:

obtaining a search condition for searching for data, and obtaining classification information indicating a classification of the data, by the search condition input unit;

generating, by the encrypted tag generating unit, an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the search condition input unit, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

transmitting, by the data search requesting unit, information of the search condition obtained by the search condition input unit with the encrypted tag generated by the encrypted tag generating unit to the data search device, and receiving as search result data from the data search device a piece of data that satisfies the search condition, from among pieces of data included in the data group of the classification indicated by the classification information.

17. A non-transitory computer readable medium storing a data search program for causing a computer to execute processes comprising:

a search condition input process of obtaining a search condition for searching for data, and obtaining classification information indicating a classification of the data;

an encrypted tag generating process of generating an encrypted tag for selecting a data group of the classification indicated by the classification information, based on the classification information obtained by the search condition input process, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key; and

a data search requesting process of transmitting to the data search device information of the search condition obtained by the search condition input process with the encrypted tag generated by the encrypted tag generating process, and receiving as search result data from the data search device a piece of data that satisfies the search condition, from among pieces of data included in the data group of the classification indicated by the classification information.

18. An information processing device, comprising:

a communication circuit; and

a processing circuit coupled with the communication circuit and configured to:

for searching for data

generate an encrypted tag for selecting a data group of a classification indicated by classification information associated with a search condition, the encrypted tag being arranged such that a decryption result of decrypting the encrypted tag using a predetermined decryption key associated with the data group of the classification matches a predetermined key-determination information stored in a data search device in association with the predetermined decryption key;

transmit, to the data search device using the communication circuit, information of the search condition and the generated encrypted tag; and

receive, as search result data from the data search device, a piece of data that satisfies the search condition from pieces of data included in the data group of the classification.

19. The information processing device according to claim 18, further comprising:

a storage device configured to store a plurality of encryption keys and a plurality of pieces of classification information by associating each of the plurality of the encryption keys with each of the plurality of the pieces of classification information,

wherein the processing circuit is configured to select an encryption key associated with same classification information as the classification information from the plurality of the encryption keys stored in the storage device, and generate the encrypted tag by using the selected encryption key.

20. The information processing device according to claim 18,

wherein the processing circuit is configured to generate the encrypted tag in accordance with an ID-based encryption scheme using an ID based on the classification information.

21. The information processing device according to claim 18,

wherein the processing circuit is configured to generate the encrypted tag in accordance with a functional encryption scheme using a vector including the classification information.

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