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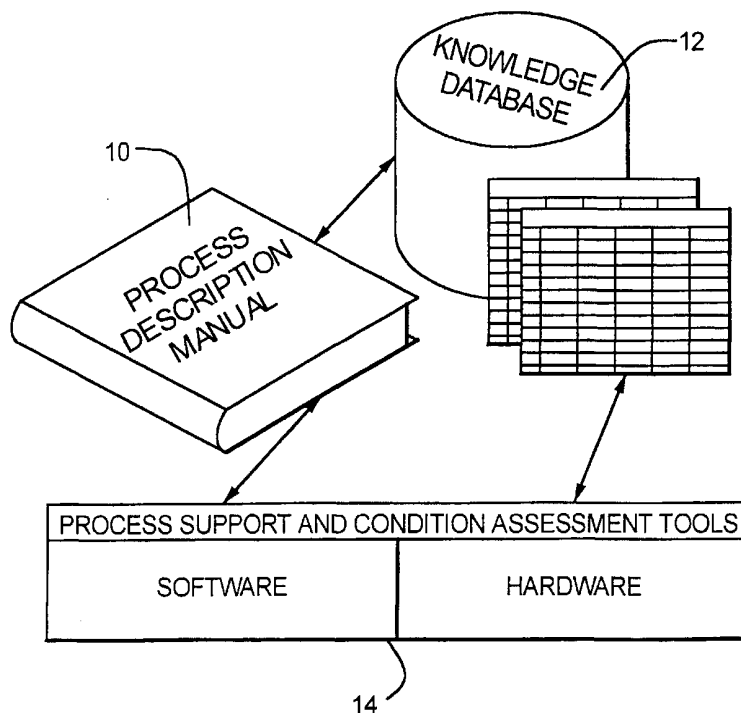
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(54) Title: PLANT MAINTENANCE TECHNOLOGY ARCHITECTURE



(57) Abstract: An overall plan for providing maintenance and technical services for businesses and plants, as broadly defined, includes generic procedures for the services written as a manual of standard practices. A knowledge base or experience database of data and people is utilized, and both hardware and software tools are selected and used in providing the services.



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## SPECIFICATION

### "PLANT MAINTENANCE TECHNOLOGY ARCHITECTURE"

#### TECHNICAL FIELD

The present invention relates generally to a method of applying and/or improving  
5 maintenance services to plants, including describing providing maintenance to plants  
potentially on an outsourced basis at all stages in the plant life cycle.

#### BACKGROUND ART

As global competition increases and supply chains become shorter, businesses are  
being forced to find new ways to increase plant performance while simultaneously reducing  
10 costs. Complexity of the business adds to the costs, and one area of significant complexity  
for manufacturing businesses is plant maintenance. In addition to adding complexity,  
maintenance can make up anywhere from 5-40% of the total costs of production. While  
maintenance is critical to the business outcome, it is often regarded as a necessary evil, and as  
a result it has been difficult to achieve sustained improvement in performance from an in-  
15 house maintenance group without intense management effort that detracts from the core  
business process.

For complete plants or, for example, production lines, it is known to provide (under  
classic maintenance contracts) fixed prices for a qualified status of the production means.  
The qualified availability is determined by the customer on the basis of his experience (which  
20 availability he must have).

Furthermore, bonus/penalty maintenance service is known; an availability variable is  
thereby determined (90 %, 95 %, 98 %, 100 %). If a better availability or 100 % is reached, a  
bonus is paid; if less is reached, there is a penalty incurred.

According to the prior art, the following maintenance services, for example, are being  
25 done for the customer: Personnel, repair service/exchange service, partially including stock  
keeping, software update or suchlike.

The previously described prior art is not the best for the customer. The customer  
needs the financially, organizationally and technically best solution.

## DISCLOSURE OF THE INVENTION

An objective of the present invention is to provide a definition and implementation of methods and tool systems to deliver value-added and integrated plant maintenance.

The present invention provides a collection of operative business and maintenance processes in a comprehensive and merged description, referred to here as a manual. The present invention also provides guidelines as well as an architecture for selecting and integrating software and hardware tools and resources to perform the process steps outlined in the manual. This includes identifying and providing best-in-class software. Resources include consultants and cooperation partners. A further aspect of the invention is to provide an experience database, termed a knowledge database or repository that includes data tools and people which are consulted either occasionally or constantly for guidance. The knowledge base includes data from project experience, regional business information, data relating to technical equipment, cost models and the like. This knowledge base forms a plant maintenance repository of historical data that is consulted for predictions of plant events, system and component failure modes and events. By consulting the knowledge base, the maintenance of the plant is optimized based on market demands and historical records.

The modules, which are implemented through software modules and hardware, are installed at a local level in each plant. However, operation and control of the service is provided through regional facilities that are linked to the local facilities by a communication connection, such as through the Internet. The regional facilities are provided at regions around the globe so as to offer 24 hour support to the local service locations, including providing a regional center in the Far East, one in the European Union, and one in a NAFTA country. One of these regional centers are open during business hours at any time of the day to provide support for the local service locations. The regional centers are in turn connected via communication links to a single world-wide headquarters.

The local installation of the software is determined by what is available locally that meets the established criteria. This provides a local flavor or local color for the software, so long as it falls in the desired class or group of software tools. For instance, a local word processor program in the native language of the country may be used as a local implementation of the tools. The tools need only meet the integration requirements established by the present

inventory as a world side strategy.

The process descriptions provided by the manual bring visibility to the support strategies of a business so that priorities may be assigned. Interfaces become transparent and experience in one region can be used in another. A continuous improvement process may be undertaken. By exchanging experience, best practices sharing can be performed so that every unit works according to the same and/or optimum rules.

Additional aspects of the invention provide written strategy and methods, understanding of know-how based on business processes and know-how based on technical processes, and integration and piloting.

Thus, the present invention provides a manual of uniform or standardized practices relating to technical services for use by plants and facilities to achieve reduced costs, greater efficiency, and higher profits. The manual is utilized along with a database of experience through secure communications channels to the plant or facility for added benefits. Software and hardware are utilized in combination, and together with the manual and experience database yields optimum financial results.

The present invention is utilized along with outsourced technical services and maintenance technology provided to plants as a part of a business strategy. According to the present invention, plants are defined broadly to include airports, steel mills, hospitals, mines, ship yards, large buildings, hotels, chemical plants, cement plants, subway systems, railway systems, container terminals, oil drilling rigs or platforms, paper mills, oil or natural gas pipeline systems, lime plants, water treatment plants including desalination, fresh water pipelining and waste water treatment, food service facilities, etc.

These services are provided at all phases in a plants life cycle, including planning of the plant, erecting the plant, mobilizing and operating the maintenance of plant and managing the shut down of the maintenance services on the plant.

The outsourced services are founded on a knowledge base comprising experienced personnel and business plans shown to have been effective, as well as of gathered historical data. An implementation of the present invention is embodied in a technical support program featuring modular services offered via a menu of services to plants. A more specific aspect of the invention is embodied in a motor management program featuring modular motor services

offered via a menu to plants. Both of these are covered in more detail in PCT applications by the present assignee, which are incorporated herein by reference. A further aspect of the invention is embodied in a menu driven management and operation technique, for which an application is being filed by the assignee of the present invention and which is incorporated  
5 herein by reference.

The present invention provides the manual as a presentation layer for presenting information on the maintenance architecture to guide and assist personnel of the services provider.

Thus, the present invention proposes a better solution for the customer, particularly to  
10 improve its financial plant result (its profit). For this purpose, the availability is adapted to the requirements of the production process, of the market, etc. (an ice factory does not need a high availability in the winter, for example; the same is valid for a gift shipping company directly after Christmas). As a result of PMTA, an optimal solution is possible for the customer given minimal costs of the individual service process, so that a particularly low  
15 service price can be offered to the customer despite a permanent availability of the service. This is his advantage.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of the main elements of the present invention, including a process manual incorporating the practices and process of the present invention,  
20 knowledge base and tools set;

Figure 2 is a functional block diagram of communications between plants and regional centers;

Figure 3 is a diagram of the world indicating plant and regional center locations;

Figure 4 is a functional block diagram of the main elements of the invention being  
25 utilized in a maintenance project;

Figure 5 is a block diagram of the information flow in the maintenance project at a plant;

Figures 6 through 11 show multiple parts of a flow chart illustrating process steps set forth in the process description manual of the present invention;

Figure 12 is a functional element diagram of an architecture of the knowledge database;

Figure 13 is a functional element diagram of the software tool sets utilized in the present invention; and

Figure 14 is a time and organization level diagram comparing the present invention to prior arrangements.

#### MODES FOR CARRYING OUT THE INVENTION

According to **Figure 1**, the present invention provides an architecture, including as primary elements a process description manual 10, a knowledge database 12 and hardware and software tools 14, for providing maintenance services to plants and facilities. The process description manual 10, the knowledge base 12 and the tool set 14 are all interlinked to one another as indicated by the arrows. This relationship will be discussed in further detail hereinafter.

The manual 10 of the present invention may be presented in a variety of forms, including on paper, electronically, via a network connection such as the World Wide Web, or on various computer media such as disks, tape or optical media. The present architecture provides a view to maintenance services as an aspect of the business effecting the bottom line of the plant, which is outlined in the manual 10. The present architecture considers maintenance services from a global view, from a regional view and from a local view.

Experience on a global and regional scale is gathered in the knowledge database 12 and used to increase bottom line profits at the local plant. The database 12 includes not only data but also experts on various maintenance issues, and these experts are made available on a regional basis for the local plants.

The tool set 14 includes both process support tools and condition assessment tools for the maintenance services, and these may include both software and hardware tools. These are chosen utilizing shared information from the global and regional information found in the manual 10 and the database 12, so that a best of class tool set is made available at the local level via a stand alone application, a server-based network connected application or via a web-based ASP (application service provider).

**Figure 2** shows the communications channels between plants at which maintenance

services are being provided and regional centers of expertise, which serve as repositories for the knowledge base, as provided according to the present invention. A plant 16 is a customer located in a first country of the world. The plant 16 is a plant according to the broadly defined term that includes airports, steel mills, hospitals, mines, ship yards, large buildings, hotels, chemical plants, cement plants, subway systems, railway systems, container terminals, oil drilling rigs or platforms, paper mills, oil or natural gas pipeline systems, lime plants, water treatment plants including desalination, fresh water pipelining and waste water treatment, food service facilities, etc.

A communication channel 18, either by wire or wireless, connects the plant 16 to a network 20, such as the Internet, and specifically the World Wide Web of the Internet. The plant 16 has access through the World Wide Web 20 to a maintenance service provider 22 which provides outsourced maintenance services to the plant 16. Preferably, a firewall 24 is provided at the communication channel to ensure security of data behind the firewall. The communication channel is carried through the service provider by a channel 26 to a center of expertise 28 located in a first region. The first region is the region of the world in which the country of the plant 16 is located. The plant 16 is able to obtain expert advice and guidance in maintenance issues by consulting with the experts and others at the center 28. The experts and others at the center 28 have at hand the data of the knowledge database 12 which is consulted as a guide.

The connection channels between the elements of Figure 2 are preferably secure connections, such as by utilizing encryption and/or other security measures. As an alternative, the communication channel between the plant 16 and the service provider 22 may be by a dedicated phone line or internal network connection, as indicated at 19. This dedicated connection 19 is through the firewall 24 for security reasons.

The plant 16 has the tools 14, both hardware and software, for carrying out the maintenance services at the plant. In some instances, the software tools may not be installed in the plant 16, but can be accessed over the network connections. The service provider 22 performs the function of application hosting, as shown at 25. The service provider 22 has at hand the process manual 10 on which the maintenance architecture is based, and the plant 16 and regional center 28 may also have the process manual 10.

The center 28 may not always be available, however, since it may be after working hours at the regional center 28. In this case, the inquiry from the plant 16 is forwarded to a second regional center 30 through a communication channel 32. The second center of expertise 30 is located in a different region of the world than the first center 28, and so is still open during its working hours. The customer 16 need not know that the second center 30 is being accessed, however, since the communication channel 32 is selected by the service provider 22 based on regional center availability.

A second plant 34 in a different country also has maintenance services provided by the service provider 22. The plant 34 consults with a regional center of expertise 30 in the second region of the world so long as the center 30 is open (on duty) and available. The communication channel includes a wired or wireless link 36 through the World Wide Web 20 and through the firewall 24 of the service provider 22 to the center 30 by a communication channel 38. If the center 30 is on duty, the inquiry is answered or the assistance is provided. However, the center 30 may no longer be on duty, so that the service provider 22 forwards the support inquiry to a third regional center 40 through a communication channel 42. As a further alternative, the plant 34 may have a direct connection 43 to the regional center 40 and so bypass the service provider 22. It is preferred in this instance to provide the regional center 40 with a firewall 24 for security.

The function of redirecting the inquiry is transparent to the plant making the request and is handled by a directory layer 23 within the service provider 22. Every center of expertise need not have the same information or expert personnel available, and so the directory layer 23 is also used to redirect inquiries to the center having the needed expertise. Multiple centers of expertise may be provided within each region, if desired. Plants in many different countries have a center for expertise available to them whenever help is needed.

In **Figure 3** is shown the world 50 indicating the locations of the regional centers 28, 30 and 40, for example. The locations of plants around the world are shown, including plants 52, 54 and 56 in a region belonging to the regional center 28, plants 58 and 60 in the region of the center 30, and plants 62 and 64 in the region of the center 40. Thus, each region of the world is covered by a regional center, and if a local center for a particular plant is off duty, another center in another region of the world is on duty and takes the inquiry. Continuous



service is therefore provided 24 hours per day, in all time zones of the world, but without requiring 24 hour staffing at any one center.

According to **Figure 4**, an execution of the maintenance is shown including the process manual that includes reference links 70 to the knowledge database 12. The knowledge base has data and process links 72 to the tools 14, and the tools 14 provide reference links 74 back to the process manual 10. The manual 10 leads to the application of the concepts to a maintenance project 76 at a plant as shown at 78. The tools 14 include individual tool elements 80 that are applied to the maintenance project 76 as indicated at 82. The maintenance project 76 is in a specific region and has specific content and is in a specific industry. Performing the maintenance project 76 requires providing initial information, which comes from the knowledge base 12 as indicated at 84. These various leads indicate the input of standard processes 86, standard methods 88, key performance indicators 90, and further information 91. The processes 86 are generally high level and include a sequence of actions to goal, while the methods are a low level and are components of the processes, generally being analytical. The further information 91 includes information illustrated and discussed in conjunction with Figure 11.

After the maintenance project 76 is running, project experience is gained, as shown at 92, The experience leads to improvements in the processes 94, methods 96, performance indicators 98 and the further information 99 (see Figure 11). These improvements are fed back as shown at 100 to the maintenance project 76. The improvements resulting from the experience 92 are also fed back to the knowledge base 12 and applied to the corresponding parts thereof, as indicated at 102. The knowledge base 12 is thus updated as new information becomes available based on experience. The knowledge base 12 is shared by all the regional centers and so is applied world wide, or may be regionalized.

The information model (data flow model) is shown in **Figure 5** for the present invention within a plant, such as plant 16. In particular, the plant is divided into operations, production and maintenance portions. The illustrated plant may include the entire plant, or may be just a portion of the plant to which the present maintenance services are provided. In the plant operations portion is found a block for enterprise resource planning 110, that includes the functions of sales 112, purchasing 114, asset management 116, accounting 118,

controlling 120 and personnel 122. The enterprise resource planning 110 is shown in dotted outline to indicate that this functional element of the plant is, or may be, in communication with the knowledge base 12, such as through a regional center 28 and is thus supported by the present maintenance services architecture.

5           In communication with all of the enterprise resource planning elements is a management portion 123 including production planning 124, quality management 126 and logistics 128. These elements of management are supported as well by the present invention and are on communication with the knowledge base 12 as shown by the dotted outline.

10           In the production portion of the plant, which represents the plants key competency, is found first and second production lines 130 and 132 and an auxiliary production line 134. The production lines each have a digital control system 136, which may be in communication with the knowledge base 12 according to the present invention. A condition monitoring system 138 is also provided for each production line, if applicable, which can be directly connected to the experts at the regional centers as shown by the dotted outline. A quality  
15           management component 140 is provided as well.

          The maintenance portion of the plant is the heart of the services that may be provided on an outsourced basis under the present invention. The maintenance portion has a maintenance decision support component 142 in communication with the condition monitoring systems 138 of the productions lines. The maintenance decision support  
20           component 142 monitored by the knowledge base 12 as shown by the dotted outline. Information from the maintenance decision support component 142 is provided to a systems analysis component 144, also linked to the knowledge base under the present method, which in turn communicates with a strategy and performance indicator component 146. Information from the maintenance decision support component 142 is transmitted back and forth with a  
25           computerized maintenance management system 148 via a bus 150 that also communicates directly with the strategy and performance indicator component 146. The computerized maintenance management system 148 which may be in communication with the knowledge base 12 according to the present invention. The bus 150 provides communications with service personnel 152 and a maintenance call desk 154 as well as to a workshop 156 and to  
30           the production planning 124 and quality management 126.

The logistics component 128 communicates to a spare parts management component 158, that also is in communication with the computerized maintenance management system 148. Also in communication with the computerized maintenance management system 148 is an engineering data management component 160, that has a connection to the knowledge base

5 12. At the lower portion of the Figure 5, the maintenance components have their own enterprise resource planning components 110 or share these functions with the operations portion of the plant, depending on company organization. The maintenance components are in communication with the components of the enterprise resource planning 110 components of purchasing 114, asset management 116, accounting 118, controlling 120 and personnel  
10 122. In this instance, personnel include the people, the software and the logic of the plant.

The foregoing is intended as an example of a business organization and is not intended to be limiting to the business structure to which the present invention may be applied.

Aspects of the process description manual 10 are shown in a flow chart of Figures 6,  
15 7, 8, 9, 10, and 11. The flow chart represents information and guidelines in one embodiment of the manual and is not intended to limit the scope of the invention. In **Figure 6**, a first portion 170 of the process manual is an introduction, followed by a section on the theory of management technology 172 and then a portion on marketing 174. Under the marketing portion 174 of the manual are parts relating to analysis of business segments 176, regional  
20 markets and priorities 178, customers 180, competitors 182, the plant's market position 184, the market position of the product sales departments 186 and a project list of product sales departments 188.

The next section of the process manual 10 relates to sales 190, including sales tools 192, presentation guidelines 194, proximity to customer 196, preference to key data 198,  
25 leaflets and brochures 200, fliers to first contacts 202, and prequalification 204. Under section 5 is found contract partners 206 for the maintenance services, which has the subsections of contract forms 208, sample contracts 210, contracts with subcontractors 212, contracts with general contractors 214, consortium contracts 215, contracts with joint venture partners 216, internal agreements with product sales departments 218, internal agreements  
30 with regions 220 and partner agreements 222.

Turning to the continuation on **Figure 7**, the manual 10 has a bid preparation section 224 for the plant. The entry point depends upon whether the plant is a greenfield plant (being built from the ground up) or brownfield plant (having an existing plant structure). The greenfield entry 226 provides for tender of an inquiry 228, and making a go/no go decision at 230. No go results in stop 232, while go results in performing a structural analysis of technical, information technology and commercial aspects at 234 as well as setting up of operations, personnel and inventory at 236. The structural analysis 234 leads to rating of the facts and plant structure 238, which includes a project repository 240 and a productivity model element 242 and reliability and maintainability 244 ( which is optional), that lead to a preconditioning for the plant and equipment design 246. Also included is a maintenance cost model 247.

The brownfield entry 248 leads to a sales inquiry contract 250 (may be followed by a preliminary questionnaire in a first visit) and a go/no go decision 252, that is embodied in a letter of intent. No go results in stop 254, while go results in setting up of operations, personnel and inventory at 236 and performing an audit (a maintenance business review) MBR on customer request 256, leading to a strategic decision 258 that may result in no bid 260. The bid process continues with a maintenance technology audit 262, that includes a project repository 264, an reliability and maintainability element 266 (which is optional), a productivity model 268 and a maintenance cost model 269. Within the scope of the audit 262 is an audit or business review process, as indicated at 276, including identifying the scope and responsibilities of the maintenance, operational process-specific requirements and restrictions, information technology specific contract terms, such as relating to reliability, liability, security and the like. Additionally, organizational and regional distribution if information technology systems, application hosting and remote monitoring. A further aspect of the audit is interfacing to the customer and identifying commonly used resources. Lastly, administrative aspects and requirements are considered.

Following the maintenance business review 262, an MBR report, or maintenance business review report, 270 is prepared with conclusions and a proposal. Following that, a customer decision 272 is made as whether the customer is seriously interested enough to bid or not to bid. The no bid decision 274 ends the process.

Additional features of the bid process are shown in **Figure 8**. For example, a bid/no bid report 276 is made. This is followed by a determination of scope of the services and supply 278, that itself includes strategy and objectives 280, maintenance organization 282, maintenance tasks and procedures 284, and preparation of an information technology plan and concept 286. The process continues with a maintenance cost estimate 288. The cost estimate 288 may be either top down 290 or bottom up 292. Either way, the cost estimate is made based on costs after consulting with subcontractors 294, considering material costs 296, personnel costs 298, information technology costs 300 and infrastructure costs 302. A marginal cost consideration 303, that includes consideration of stock 301, productivity 299 and labor savings 297.

After a cost estimate is prepared, a risk analysis 304 is performed. This leads to pricing 306 of the project. The pricing is determined by specific pricing rules 308 according to the contract and key performance indicators. A quotation is offered and contract negotiations 309 commence. Finally, the contract 310 is prepared, using provided contract forms 312.

Following the bid process 224 is a mobilization process 320 as shown in **Figure 9**. The mobilization includes a multi step fitness plan 322 for the plant. Some of the steps can be conducted concurrently. The first step of the fitness plan is a business plan 324, that includes elements of alignment, identification of key figures and preparation of a team and a schedule. The business plan is followed with alignment meetings 325 with the customer. The second step of the fitness plan provides a maintenance policy and operation plan 326, which includes the elements of identifying maintenance objectives and policy 328 and a maintenance process definition 330. In the next step, the maintenance plan is set up and improvements are made 336, including implementing standard operation plans 338, escalation strategy and emergency plans 339, establishing a maintenance plan repository 340, a machine failure mode and effects analysis (MFMEA) 342 and reliability centered maintenance (RCM) 344. The RCM can be ongoing process continuing beyond the mobilization phase. A quality maintenance setup step 345 is next, with quality, health and safety issues being addressed 343 and environmental standards review 341. After that, resources are set up 346, including assembling personnel 348, equipment and tools 350,

infrastructure 352 such as an office, a warehouse and workshop, implementing information technology 354, implementing CMMS and implementing CM and MDS. A reporting system 360 is established as a further step, and lastly, a maintenance project manual 362 is prepared. The project manual 362 is used during the start up and training operations 364 of the plant, including training on maintenance policy 366, maintenance processes 368, maintenance methods 370, maintenance technology 372, and maintenance systems and components 374. This completes the fitness plan as outlined in the manual, as indicated by the embracing line 376.

Operation of the plant is covered in section 8 of the process manual 10, as shown at 378 in **Figure 10**. Areas addressed in the operations part of the process manual 10 are either more operational or more strategic, as indicated at 380, include purchasing 382, scheduling and planning 384, maintenance process execution 386, spare parts warehousing and operation of a repair shop 388, ongoing training 390, controlling 392, keeping up a reporting project repository 394, and management of quality, health and safety and environmental issues 396. A customer project meeting 398 may be conducted. These aspects all fall under the operational aspects. A further aspect of the operations is a strategic aspect, including a claim agent 400, providing continuous improvement 402 of the following processes: a maintenance strategy with a multi-step fitness plan 404, the maintenance processes 406 and the maintenance objectives and resources 408.

Once the plant is to be shut down or the maintenance contract ends, the manual 10 covers demobilization 410 in section 9. This includes considering equipment and tools 412, infrastructure 414, personnel 416 and spare parts 418, as shown in Figure 10. Another aspect of the demobilization is transfer 420 of intellectual property, of liabilities, of ownership rights and licenses. Lastly, a final accounting 422 is made.

**Figure 11** shows further aspects of various issues addressed in the process manual 10. The left most column relates to classes of information while the corresponding rows extending to the right is the information in that class. First is key maintenance processes 424, such as corrective maintenance 426, preventative maintenance 428, condition-base maintenance 430, trouble shooting 432 utilizing a failure reaction and corrective action system, a continuous improvement process 434 and life cycle management 436. The methods

438 utilized according to the manual include: machine failure mode and effects analysis and failure tree analysis 440, life cycle analysis 442, operational analysis 444, reliability centered maintenance 446, root cause failure analysis 448, balanced score cards 450 and maintenance process simulation 452. Various models 454 are used, including a multi-step fitness plan  
5 456, a cost model 458, a productivity model 460, a manufacturing system model 462, and industry specific plant process diagrams 464. Within the information technology framework 466 is applied information models 468, information technology integration and interfacing 470, and teleservices 472 (which include personal heads-up displays as guides to local maintenance personnel).

10           Reporting 474 aspects include reporting of key performance indicators 476, and industry specific benchmarks 478. In the projects repository 480 is provided a project scorecard 482, maintenance plans for subsystem equipment 484, processes 486, methods 488, models 490 and metrics 492. A portion directed to contracting partners 494 is provided as well, which is broken down to centers of excellence 496, internal experts 498 and external  
15 experts 500.

          Referring now to **Figure 12**, an overview of data and archives in the knowledge database 12 is shown including a store 502 of diagnostic data for analysis of know-how, diagnostic models, forecasting and cost/benefit models. This provides maintenance decision support. A communications link 504 to a maintenance management systems store 506 with  
20 EDM/PCM data for drawings, specifications, tolerances, parts lists, etc., ERP/PPS data with materials and resources costs, and a production plan and maintenance object data with plant hierarchy, maintenance and work orders, maintenance costs, materials, and the like. Condition monitoring data storage 508 is linked through another communication link 510 to digital control systems 512 which perform processes on data at 514 such as process, operating  
25 and quality data, log. data, archives, non-conforming reports, calibration, control parameters and throughput times. These processes are performed using various computers, including network computers and personal computers.

**Figure 13** shows the software tools utilized according to the present invention. Plant maintenance technology architecture includes as components computerized maintenance  
30 management systems (CMMS) 516, maintenance decision support (MDS) 518, conditioned

monitoring systems (CM) 520, digital control systems (DCS) 522, and strategy optimization systems (SOS) 524. In addition, it utilizes enterprise resource planning (ERP), and manufacturing resource planning (MRP) 526 and engineering data management (EDM) 528.

Referring to **Figure 14**, information technology integration and software standards are decisive as competitive factors in industry. The present invention provides an integration framework 530 linking standard software and enterprise resource planning 532 at the management level and to software 534 at the automation level through a planning level and a command level. Reliance on individual software 536 and on hardware 538 is reduced. Information technology influence 540 is driven top down from the management level while technology influence 542 is driven upward from the field level. Consistent standards and ease of use are realized. This is a substantial improvement over the past wherein various applications 544 were used at the management level and communicating with individual software 546 at the automation level that in turn was based on hardware 548. An intermediary step has begun to be used which attempts to link standard management software 550 to standard automation software 552 via overlapping partial solutions 554. Neither of these lead to the consistent standards and ease of use of the present invention.

Thus, plant maintenance technology architecture meets its objectives of creation of standardized procedures and reference processes and the development of assessment models as a decision basis for business based maintenance. It defines, structures and implements the frame-work for methodological knowledge acquisition. Further it provides an integration concept for universal and global information technology support. The plant maintenance technology architecture is formulated to meet market demands with trend setting factors including shareholder value increases due to cost awareness, increases in consequential shut down costs, increases in the volume of safety, environmental and certification instructions. Customers expect global and standardized services. Factors which are critical to success include process analysis and plant know-how, a network of maintenance competence, pooling of resources, standardized maintenance methodology, and cross sector best practices. This leads to increased customer benefit. In-house maintenance is decreased while outsourced business based maintenance is increased.

In summary, the concept behind plant maintenance technology architecture is to



provide an umbrella under which is offered methods and processes, knowledge based business processes, and knowledge based technical processes. Underlying these is integration which uses standards and innovative information technology solutions and provides global, consistent and uniform provision of information. The methods and processes offer a design  
5 of a uniform maintenance process, establishment of standards for globally applicable methods and reference processes, and development of assessment models both in the technical and in the commercial sense. Such development may include life cycle costs. The knowledge based business processes implement asset management concepts, target maintenance strategy definitions and implementations, collect and consolidate existing know-how, and derive best  
10 practices from business and maintenance processes. The knowledge based technical processes offer increased productivity of plants, systematic utilization of plant know-how, modules for decision support, and performance monitoring.

The methods and processes portion define and harmonized the plant maintenance technology architecture. Process descriptions for definition of the maintenance programs and  
15 applications of method are offered. Definition of reference processes and cost models are utilized as standards. A determination of key metrics are made for process evaluation. A process module for systematic acquisition and dissemination of the know-how is available. The creation of an internal communication and training concept is also applied.

The knowledge based business processes offer scalable solutions for asset  
20 management in accordance with the relevant requirements. Establishment of a score card-based optimization system for maintenance strategy is done. Implementation and transfer of the strategy results to the operative management system using computerized maintenance management systems is accomplished. Know-how generation modules for a strategic performance differentiation are provided in addition to a leading competitive edge through  
25 certified maintenance management. The knowledge based technical processes offer total productive maintenance and optimization of the plants based on continuous improvement processes. On-line performance monitoring of the plants is offered. The development of a maintenance decision support methods and modules for diagnosis, optimization and residual life estimation are offered. An integration of existing databases containing descriptions of the  
30 product, system or plant behavior are available for technical modeling. For example, these

relate to wear models. For a commercial condition monitoring, preparation of an evaluation model and competence structure is provided.

Integration of all of the foregoing is accomplished through development of a plant maintenance technology information model, taking standards and strategic system platforms into account. Evaluation of and active support of important standardization activities are accomplished in the maintenance system. Innovative technologies for teleservice and virtual team support are provided. Effective mechanism for experience exchange and knowledge management are installed. And lastly, piloting of methods and solutions modules with selective customers is performed. Each of these is accomplished by repeated reference to a manual of procedures.

The plant maintenance technology architecture is built on a pyramid, the base of which is provided by the knowledge base which is overlaid with the methods and tools and processes and topped off by the process manual. The customer who purchases maintenance services realizes improved bottom line results after implementing the present invention. In particular, plant availability is matched to the market demands while maintenance costs per goods produced are reduced. Strategic knowledge advantages are realized through outsourcing of the maintenance services.

For the provider of the maintenance services, more effective customer care and acquisition is provided, along with more efficient performance of maintenance services through access to comprehensive business and maintenance process descriptions, and through integrating tool-sets and learning experiences into a database.

#### INDUSTRIAL APPLICABILITY

The present invention finds industrial applicability in utilization to offer maintenance services to industrial plants, for instance.

Although other modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

**WE CLAIM:**

2           1. Customer-related technical services for obtaining an optimal financial result of a  
production plant by continuously applying the steps of:

- 4           a) providing a process description;  
b) utilizing connected software tools and hardware tools; and  
6           c) consulting an empirical database of experience.

8           2. Customer-related technical services as claimed in claim 1, wherein the step of  
providing a process description is performed worldwide according to the same criteria.

10           3. Customer-related technical services as claimed in claim 1, further comprising the  
steps of:  
utilizing homogenous forms of marketing/acquisition, standard basic contract forms, standard  
12           offer management, mobilization, operation and demobilization.

14           4. Customer-related technical services as claimed in claim 1, further comprising the  
step of:  
performing the processes in a standardized fashion according to defaults of a manual.

16           5. Customer-related technical services as claimed in claim 1, further comprising the  
steps of:  
18           utilizing a same course of action worldwide;  
providing best practice sharing with respect to internationally comparable standards; and  
20           introducing continuous improvement processes on a basis that is always the same.

22           6. Customer-related technical services as claimed in claim 1, further comprising the  
step of:  
describing internal and external processes in a manual, the internal processes run on a  
24           customer plant.

26 7. Customer-related technical services as claimed in claim 6, wherein the manual is in writing in at least one of text form and diagram form.

28 8. Customer-related technical services as claimed in claim 6, wherein the manual is in a form readable by a personal computer and which can be printed.

30 9. Customer-related technical services as claimed in claim 8, wherein the manual is on a CD-ROM.

32 10. Customer-related technical services as claimed in claim 6, wherein the manual is on the World Wide Web.

34 11. Customer-related technical services as claimed in claim 10, wherein the manual is in an encoded form that can only be retrieved by a password.

36 12. Customer-related technical services as claimed in claim 6, wherein the manual is embedded into a virtual scene and includes simulation possibilities.

38 13. Customer-related technical services as claimed in claim 6, wherein the manual has a portal with selection possibilities for different technical services in its form that can be executed on the PC.

40 14. Customer-related technical services claimed in claim 6, further comprising the step of:  
42 subjecting content of the manual to a dynamic process which derives from an integration of a dynamically growing experience database into the manual.

44 15. Customer-related technical services claimed in claim 6, wherein the manual takes product-specific bits of information and plant-specific bits of information from experience  
46 databases from worldwide plants having a same production target and the same production

methods.

48           16. Customer-related technical services as claimed in claim 1, wherein technical  
developments as well as methodical developments are a part of the experience database.

50           17. Customer-related technical services as claimed in claim 6, wherein the manual  
contains a work flow for maintenance teams.

52           18. Customer-related technical services as claimed in claim 1, wherein the manual  
suggests method groups and methods as work instructions dependent on the work flow.

54           19. Customer-related technical services as claimed in claim 6, wherein the manual  
organizes a consideration and the following implementation of the workers utilizing centers  
56 of excellence, said centers of excellence having special knowledge.

              20. Customer-related technical services as claimed in claim 19, wherein the  
58 maintenance work is carried out by local units supported by the centers of excellence.

              21. Customer-related technical services as claimed in claim 19, wherein the centers of  
60 excellence are distributed and networked such that it is always possible to access resources.

              22. Customer-related technical services as claimed in claim 21, wherein the resources  
62 are experts.

              23. Customer-related technical services as claimed in claim 22, wherein the experts  
64 can be reached 24 hours a day.

              24. Customer-related technical services, further comprising the steps of:  
66 providing a system for implementing services with individual components which are  
obtainable on the market, said individual components being connected to a web-based

68 knowledge-based database that continuously works with experience values.

25. Customer-related technical services as claimed in claim 24, wherein the individual  
70 components are software tools.

26. Customer-related technical services as claimed in claim 1, further comprising the  
72 step of:  
utilizing external data and external tools for supplementing.

27. Customer-related technical services as claimed in claim 19, further comprising  
74 the step of:  
76 transmitting data in an encoded fashion between the centers of excellence and the local units.

28. Customer-related technical services as claimed in claim 1, further comprising the  
78 step of:  
improving standard software utilizing originally present experience data and improved  
80 experience data, said standard software being supplemented by experiences present in  
the database, utilizing worldwide knowledge therefor.

29. Customer-related technical services as claimed in claim 1, further comprising the  
82 step of:  
84 monitoring a condition of the plant utilizing remote expert centers.

30. Customer-related technical services as claimed in claim 1, further comprising the  
86 step of:  
providing an application service host that is one of centrally arranged and arranged remotely  
88 connected by the Internet, distribution and data forwarding ensues worldwide.

31. Customer-related technical services as claimed in claim 30, wherein the  
90 application service host is isolated from the individual customer programs and has fire walls

between the customers, so that the customer data cannot be viewed externally.

92           32. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

94       collecting data from all customers and OEM's in an anonymous fashion using a central  
database.

96           33. Customer-related technical services as claimed in claim 32, wherein the central  
database is on distributed servers.

98           34. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

100       selecting databases by a portal.

102           35. Customer-related technical services as claimed in claim 34, wherein the step of  
selecting is by menu prompting.

104           36. Customer-related technical services as claimed in claim 32, wherein the  
experience database represents reference data from a provider's projects and customer  
projects, OEM data, industrial standard data, project experience data from other projects,  
106       standard maintenance, and standard operating plans.

108           37. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

110       modifying OEM defaults and utilizing modified defaults when the OEM defaults are not  
advantageous for the customer.

112           38. Customer-related technical services as claimed in claim 37, wherein said  
modified defaults are maintenance intervals.

39. Customer-related technical services as claimed in claim 1, further comprising the  
114 step of:

internationally acquiring experience data;

116 organizing said experience data in a business-specific and system-specific manner; and  
using key performance data and key performance indicators.

118 40. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

120 providing feedback loops for performing the services with a start at the original plant  
condition data.

122 41. Customer-related technical services as claimed in claim 40, wherein plant start  
data serves to introduce initial measures.

124 42. Customer-related technical services as claimed in claim 41, further comprising  
the step of:

126 learning within a framework of measures how the plant reacts to the initial measures; and  
deriving further measures for improvement from the learning step.

128 43. Customer-related technical services as claimed in claim 41, further comprising  
the step of:

130 entering an effect of measures into the experience database, as well as key performance data.

44. Customer-related technical services as claimed in claim 41, further comprising the  
132 step of:

introducing a request for changing the procedure which is business-specific into the manual.

134 45. Customer-related technical services as claimed in claim 41, further comprising the  
step of:

136 introducing modified methods and tools into the manual due to the necessary changes in the



procedure.

138           46. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

140   improving services by

a) a database,

142   b) a manual,

c) local project experiences, which are directly realized, and

144   d) an improvement of the software tools and hardware tools.

146           47. Customer-related technical services as claimed in claim 1, further comprising the  
step of:

providing that tools for improvement permanently communicate with the database.

148           48. A method of providing maintenance services at a plant, comprising the steps of:  
providing a manual of operating principles common to all plants; and

150   providing further information of operating principles common to all plants of a type of plant.

152           49. A method as claimed in claim 48, wherein said further information is provided  
through a network of computers.

154           50. A method of providing maintenance services at a plant, comprising the step of:  
providing processes for addressing maintenance issues at the plant for each of a plurality of  
stages in a life of said plant.

156           51. A method as claimed in claim 50, wherein said stages include mobilization,  
operation and demobilization.

158           52. A method as claimed in claim 50, wherein said process includes providing tools  
for predetermined tasks, said tools being defined generically and being selected locally to said

160 plant.

162 53. A method as claimed in claim 50, wherein said processes for addressing  
maintenance issues are driven by bottom line considerations for said plant.

164 54. A method for providing maintenance services at a plant, comprising the step of:  
providing a knowledge repository of information specific to plants of the type of said plant.

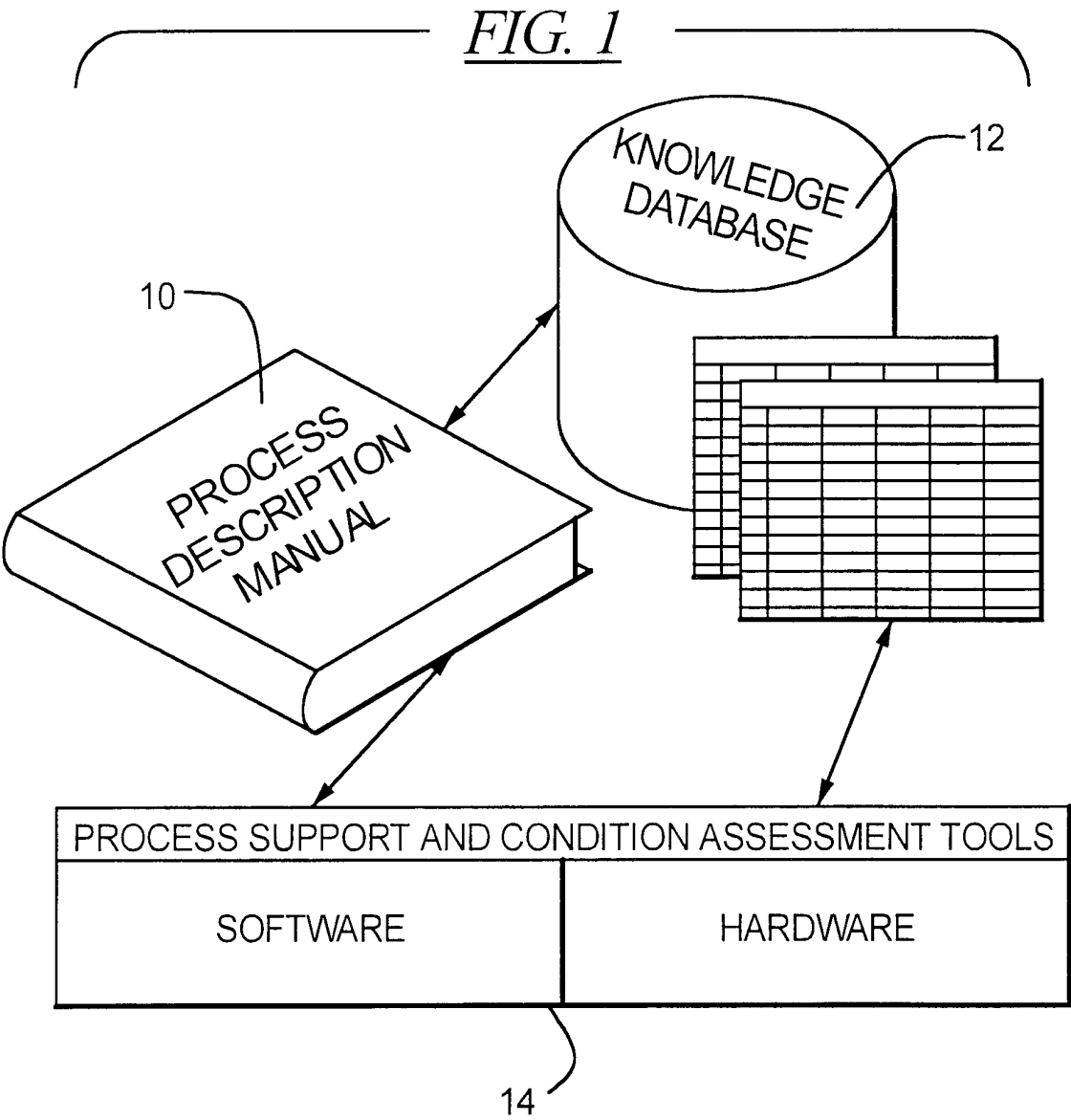
166 55. A method as claimed in claim 54, wherein said knowledge repository includes a  
database of information and experts selectively in communication with said plant.

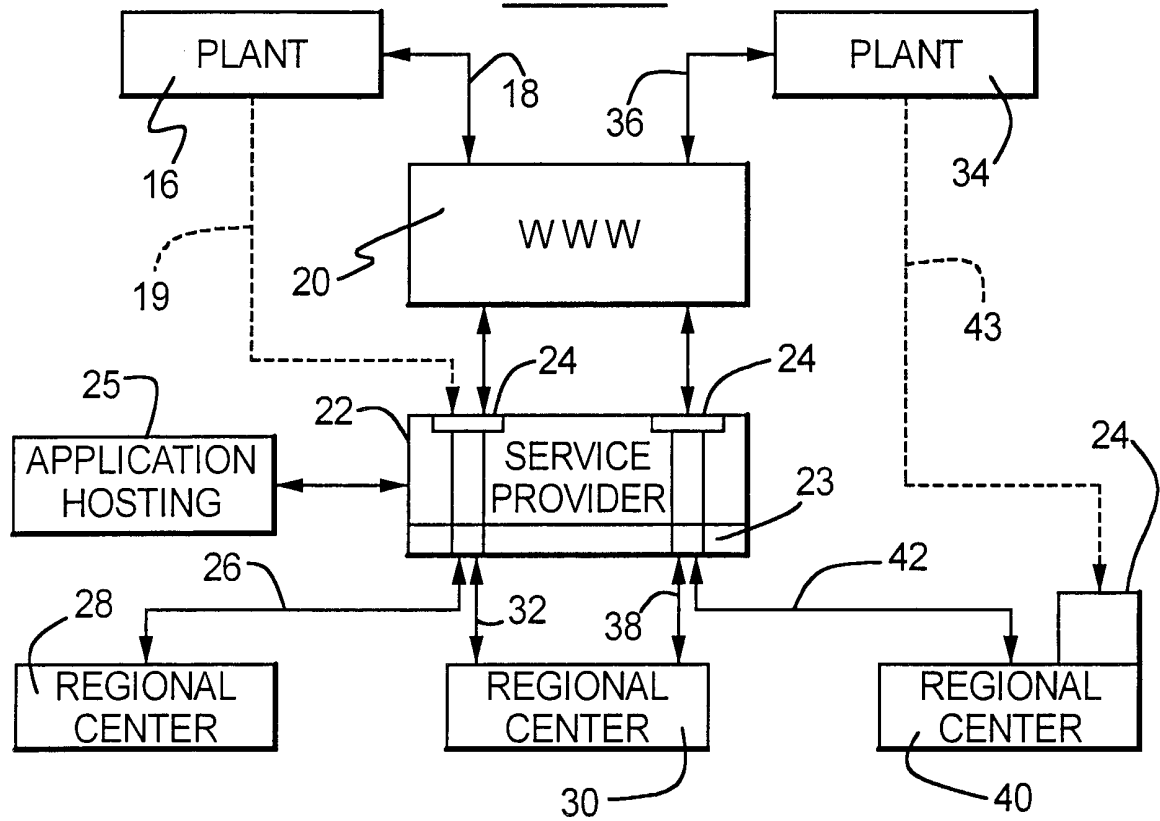
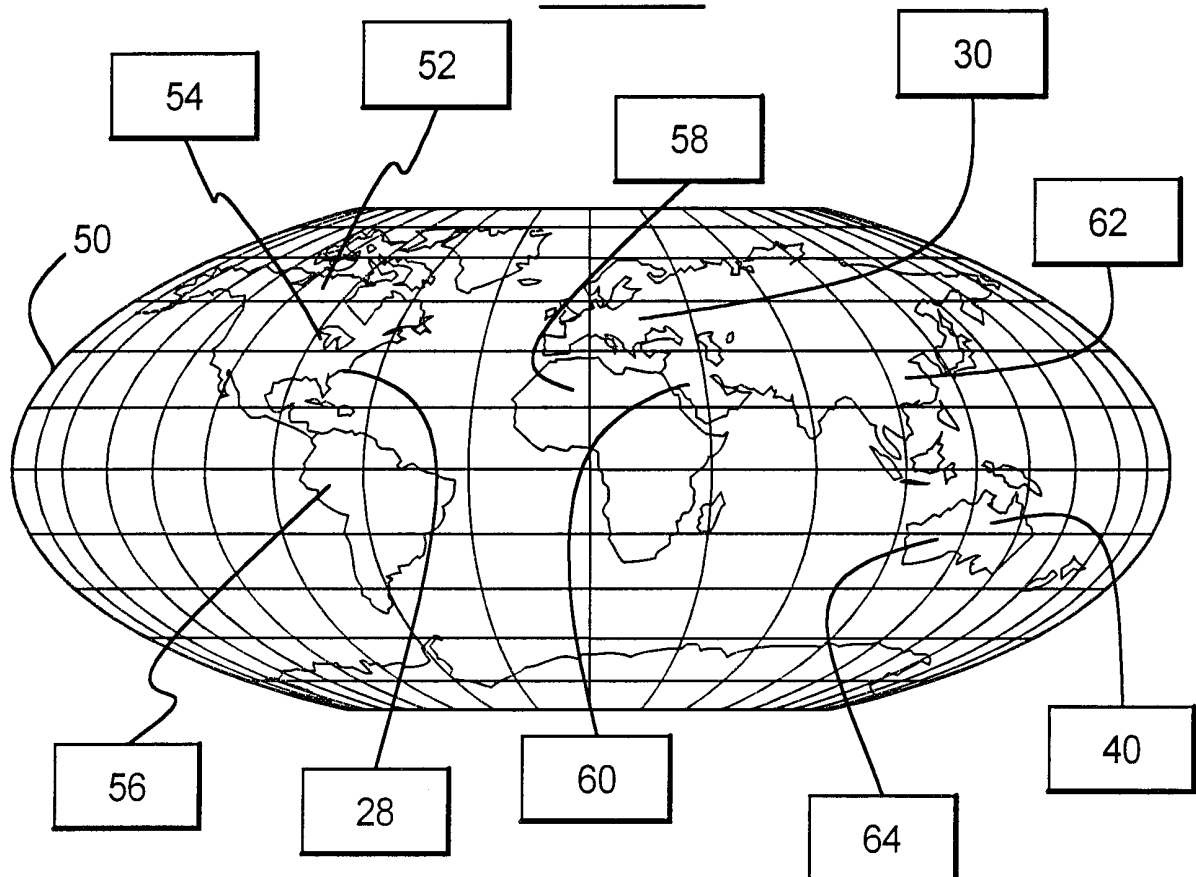
168 56. A method as claimed in claim 54, wherein said experts initiate communication to  
said plant.

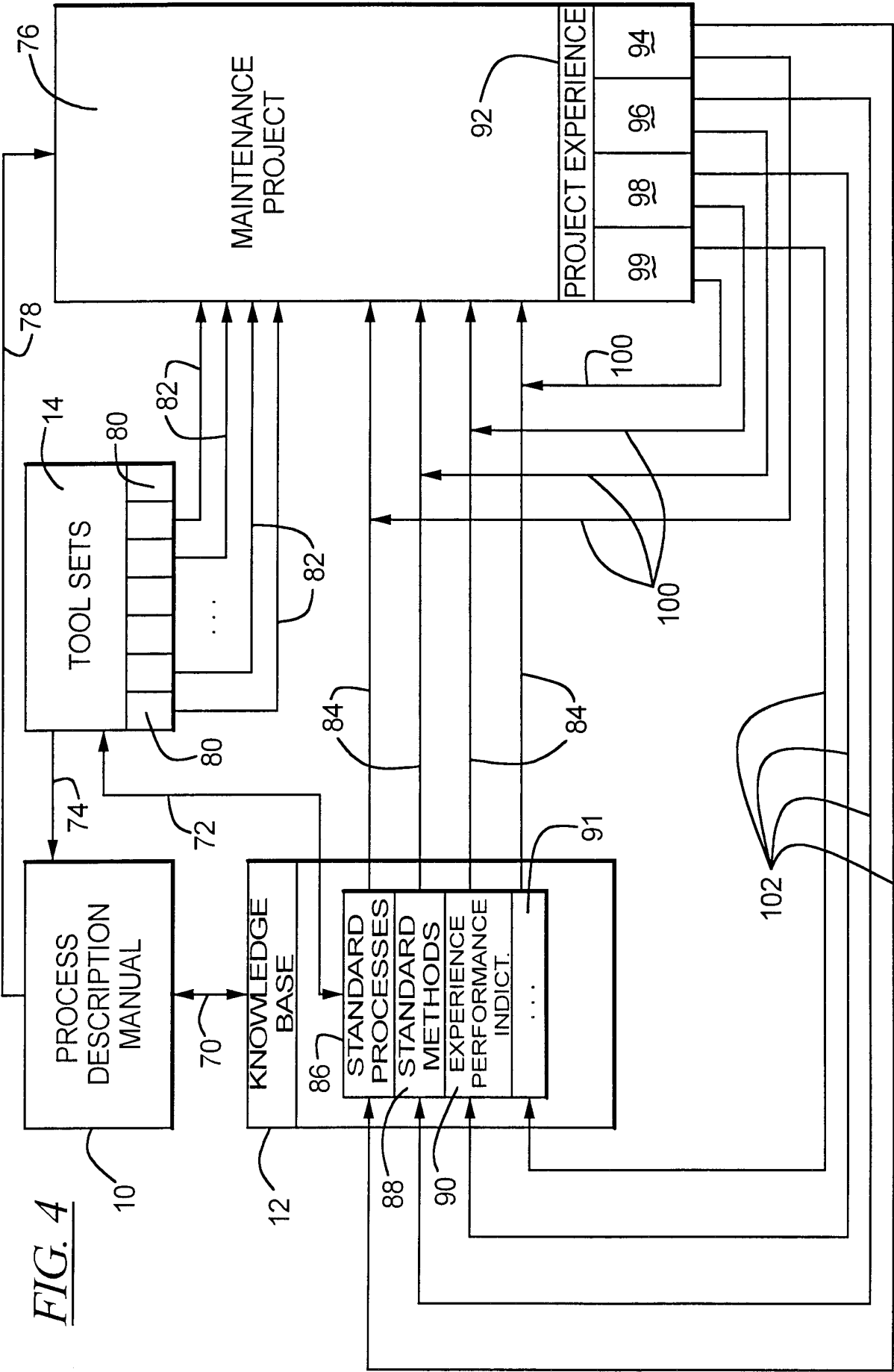
170 57. A method as claimed in claim 54, further comprising the step of:  
providing teleservices for technical assistance in maintenance of said plant.

172 58. A method as claimed in claim 57, wherein said teleservices includes providing a  
heads-up display and person mounted camera for remote examination of said plant by said  
experts.

174 59. A method as claimed in claim 58, wherein said heads-up display includes  
overlays for identification of parts of said plant.



*FIG. 2**FIG. 3*



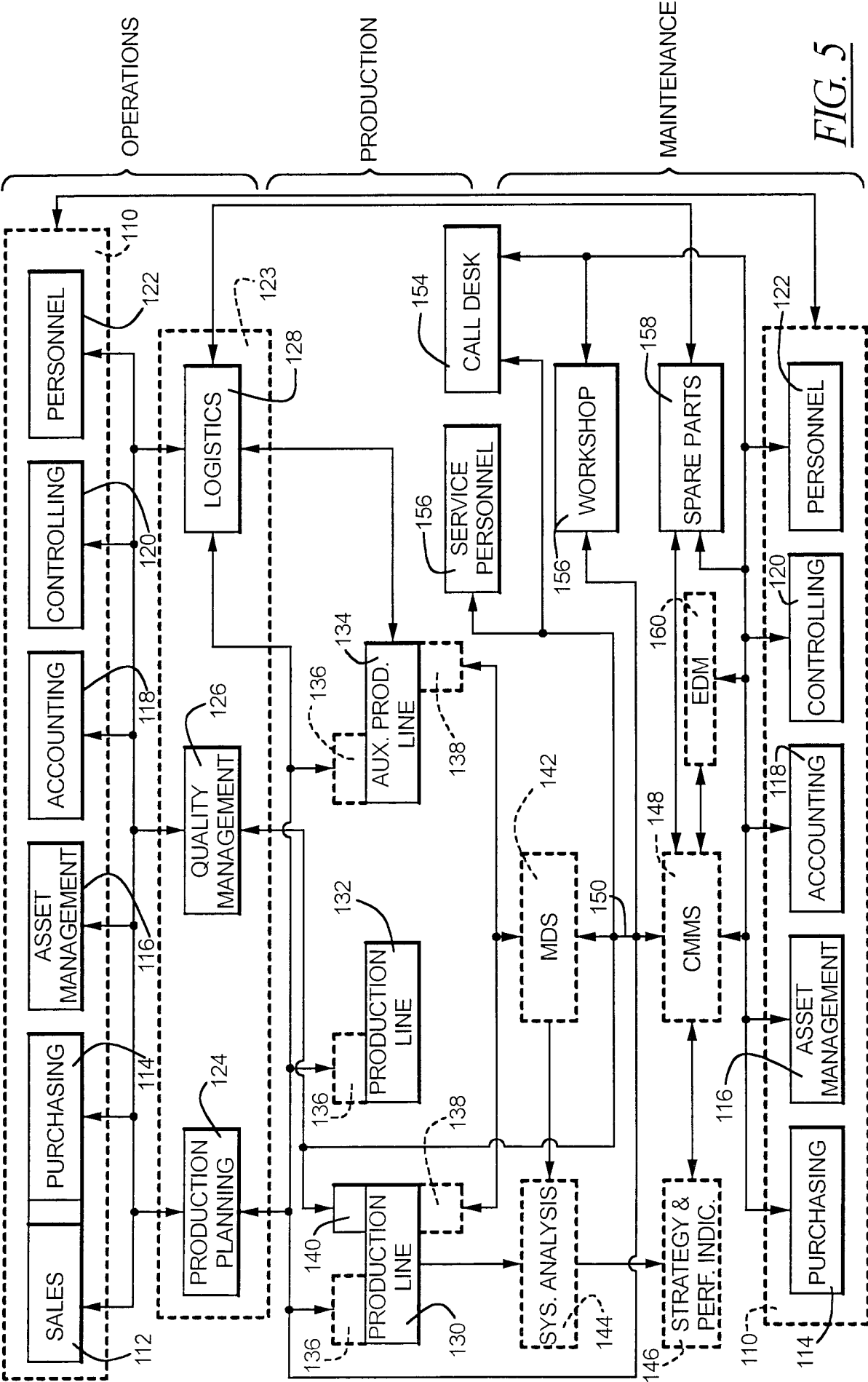


FIG. 5

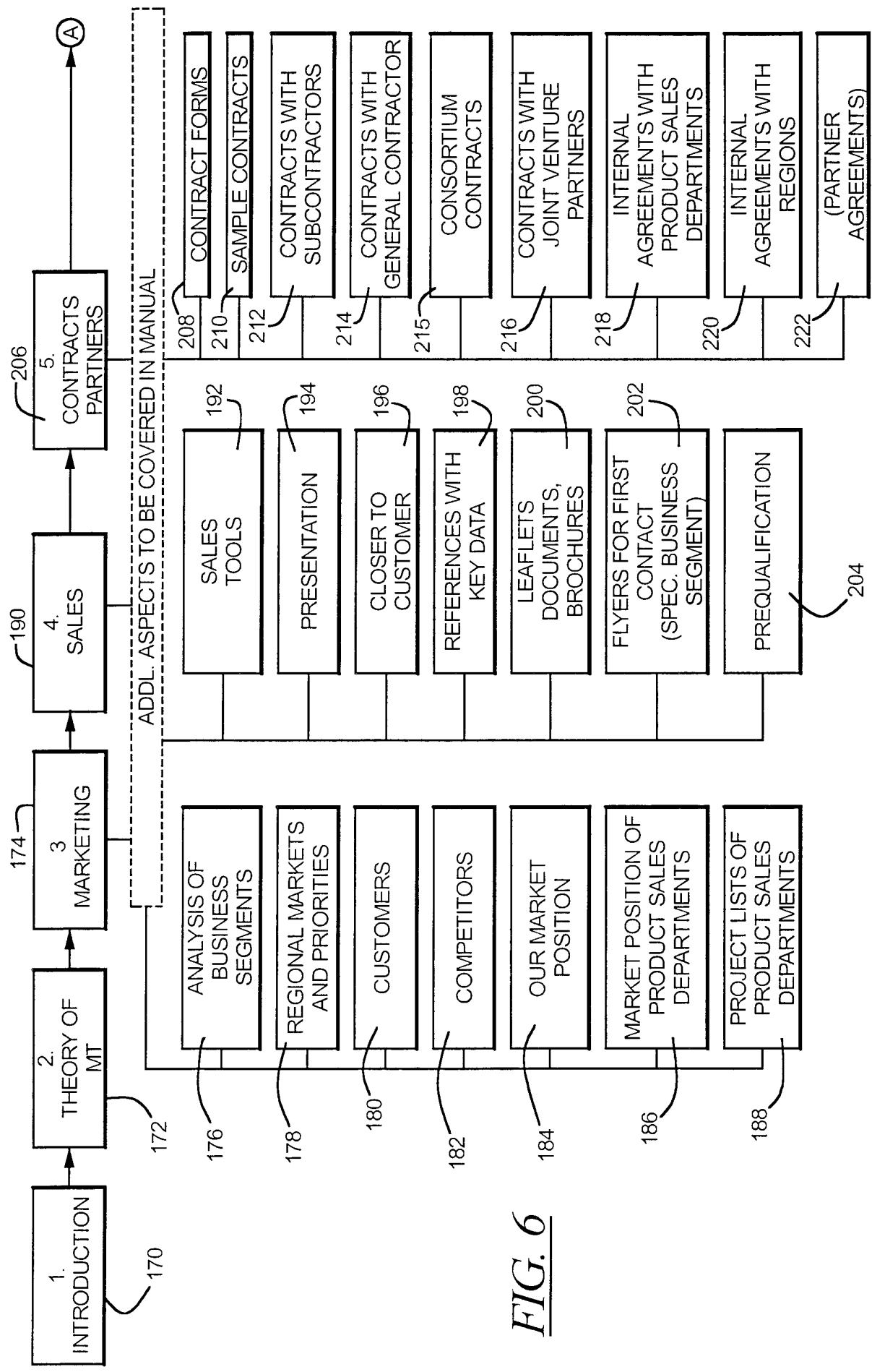
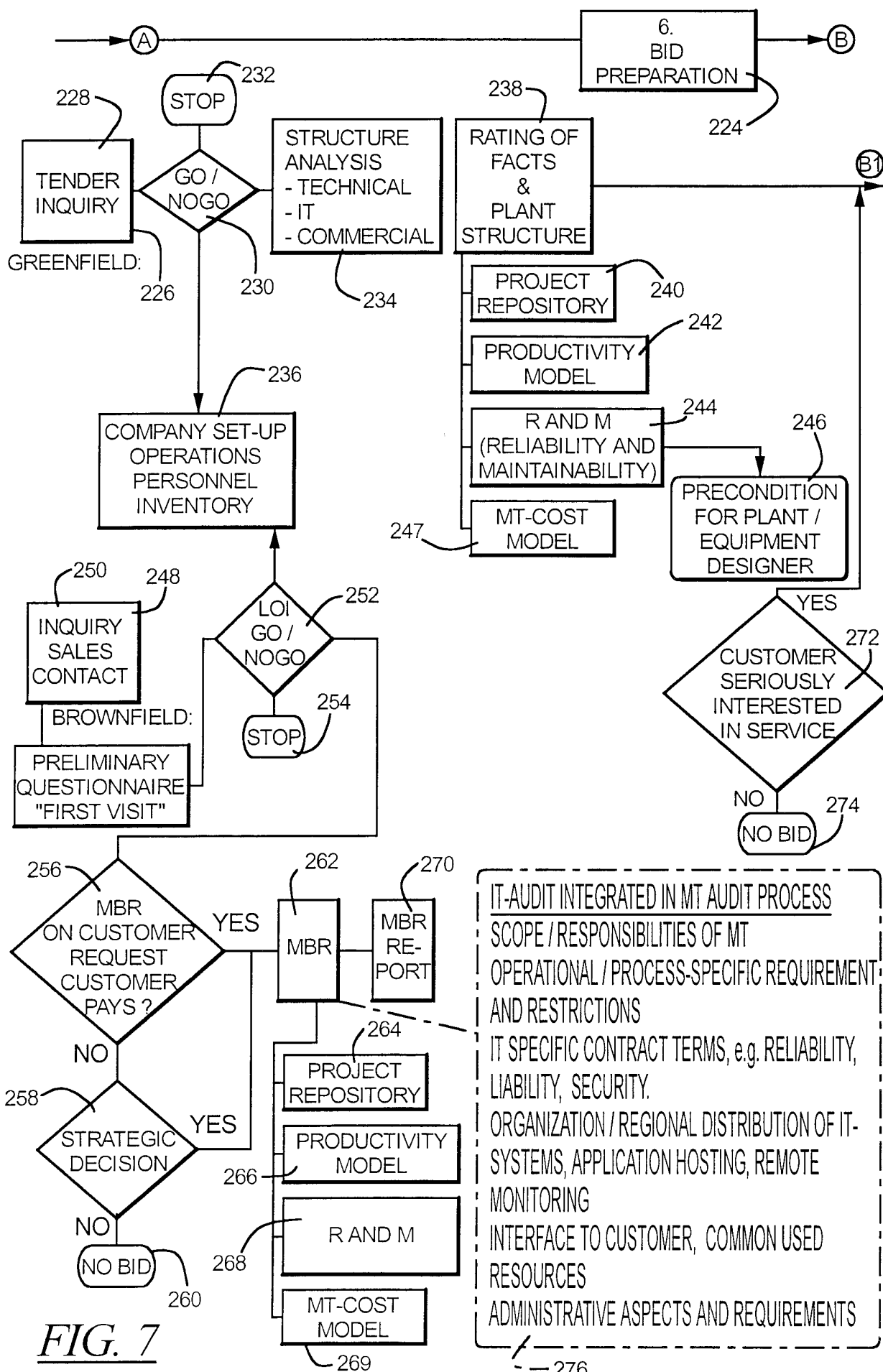
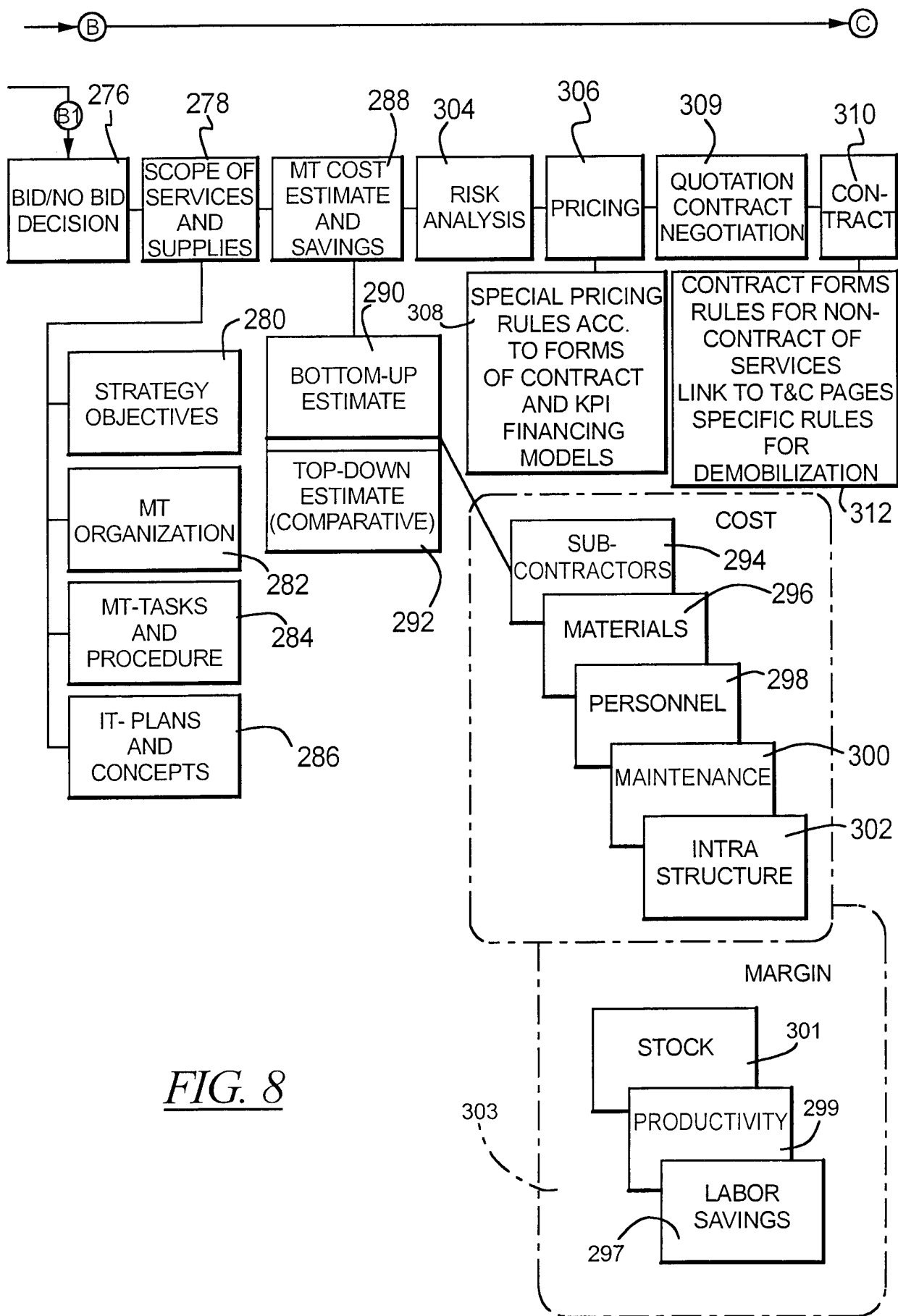


FIG. 6







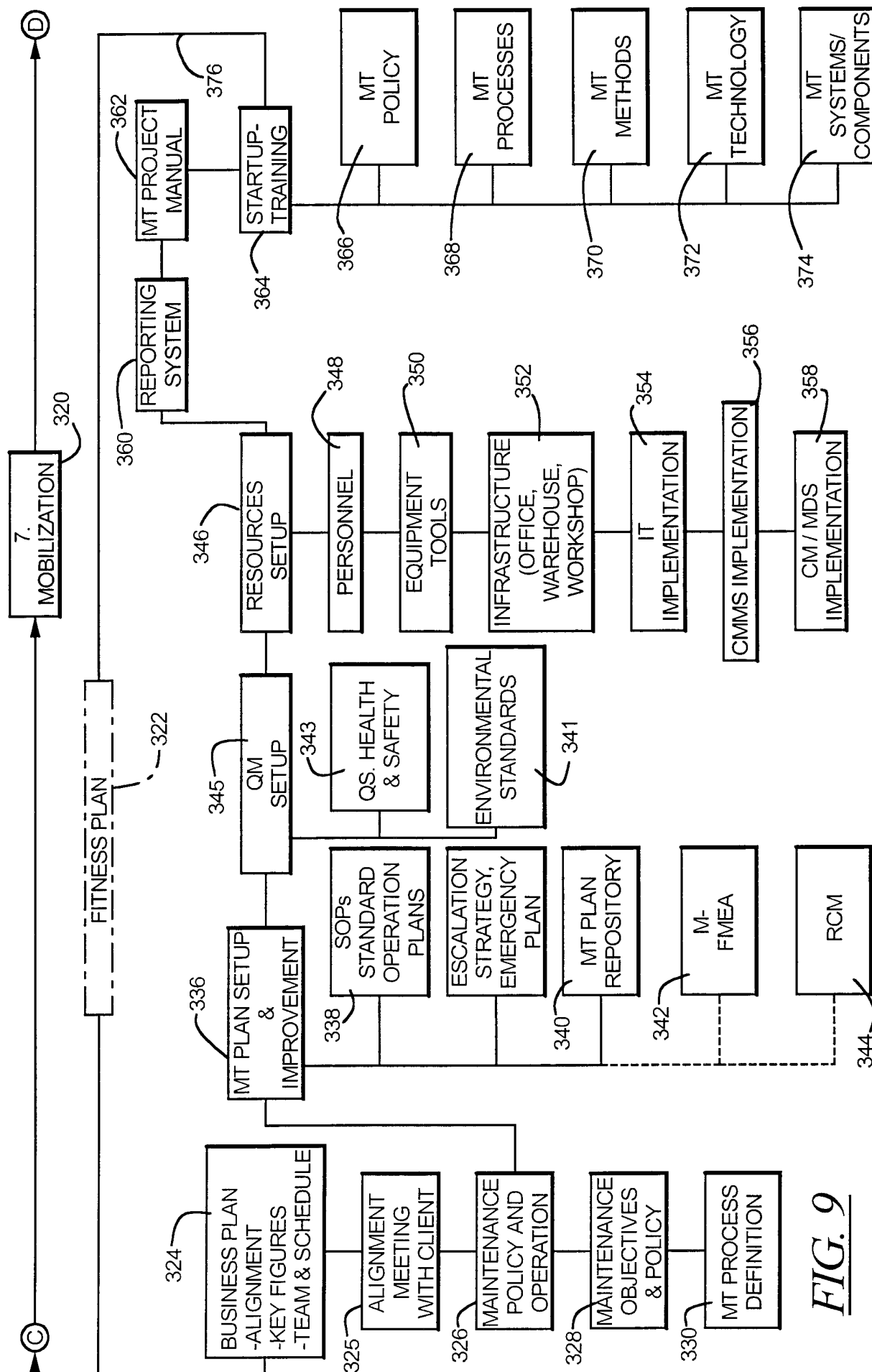
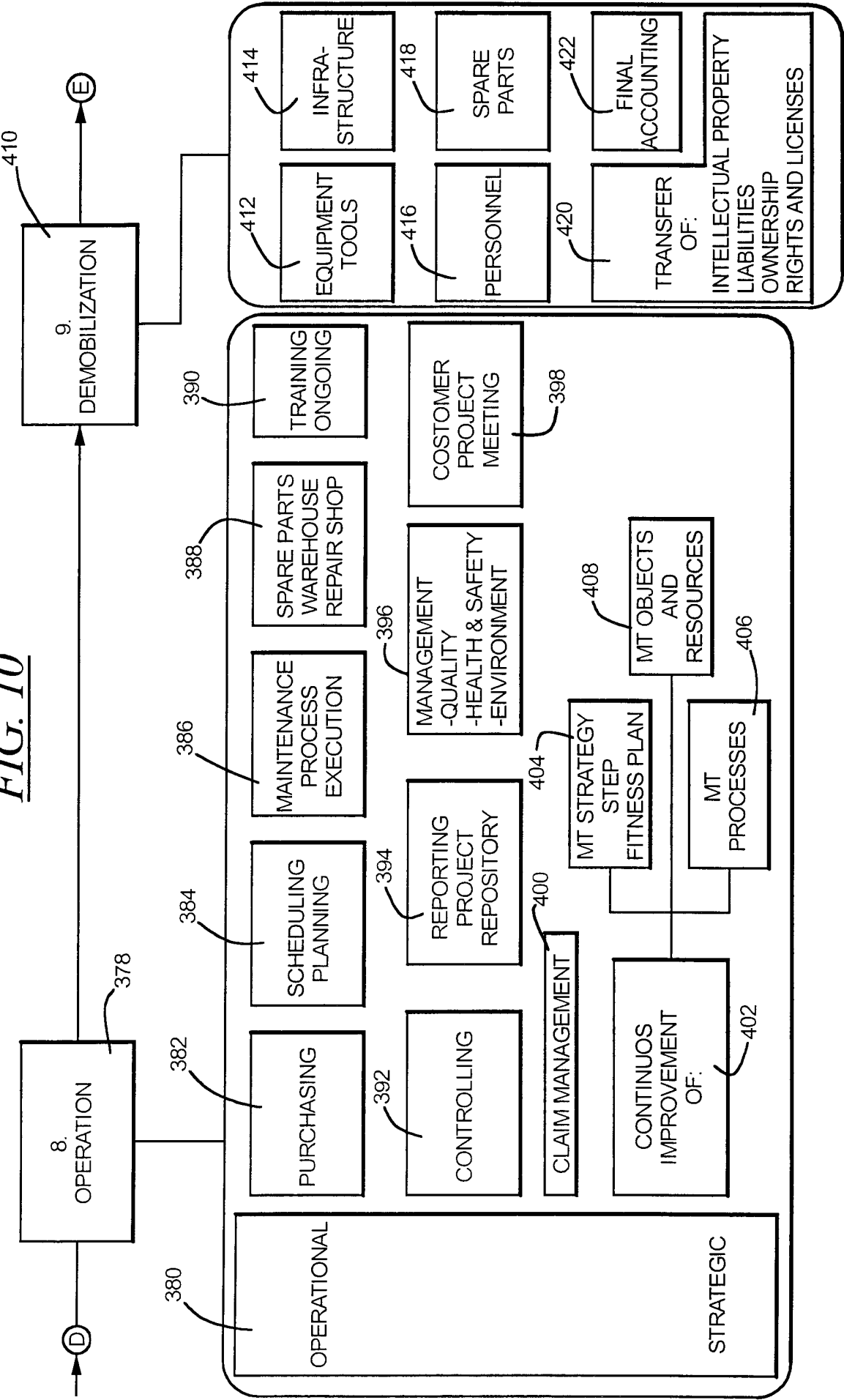


FIG. 9

FIG. 10



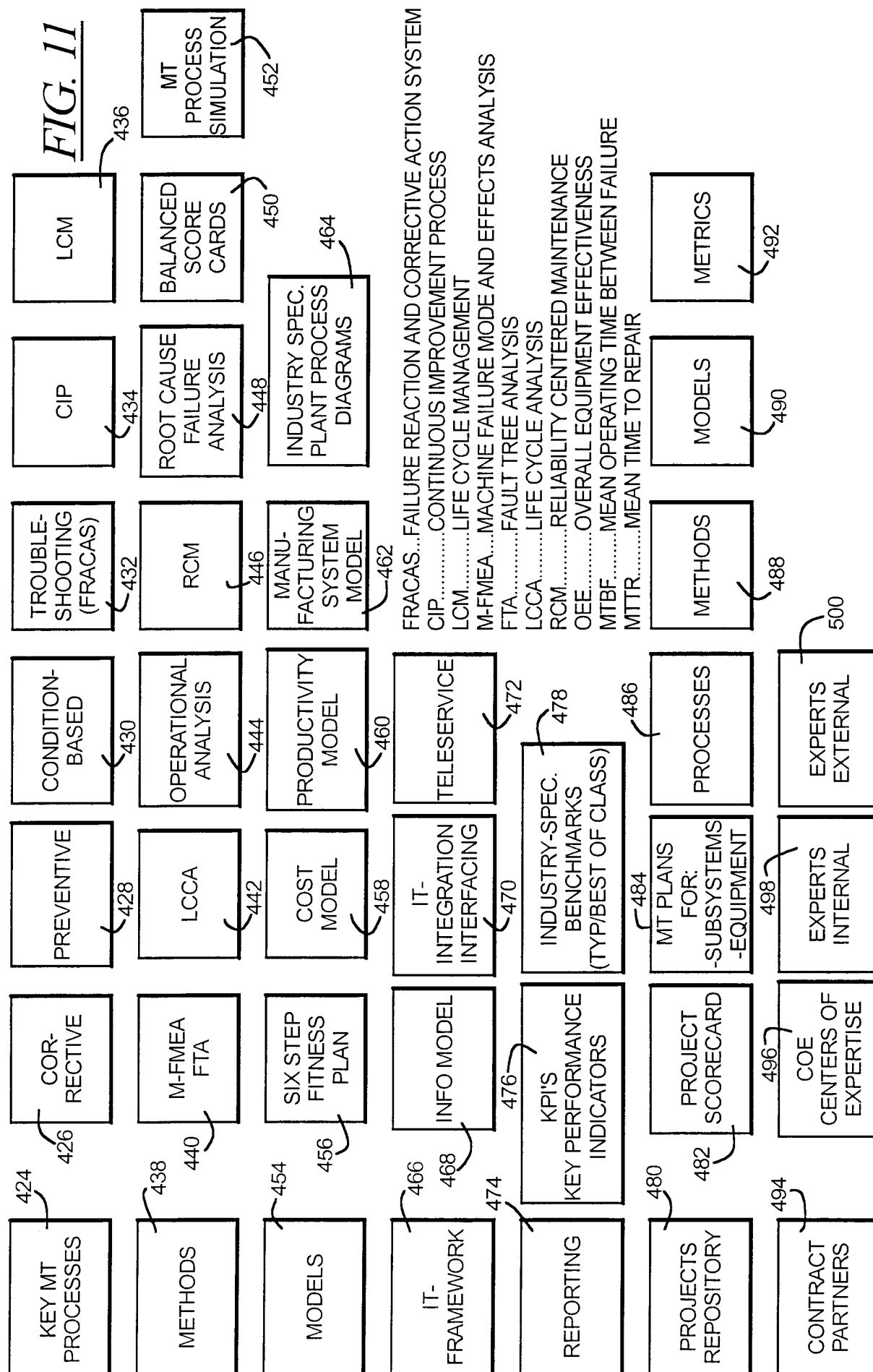
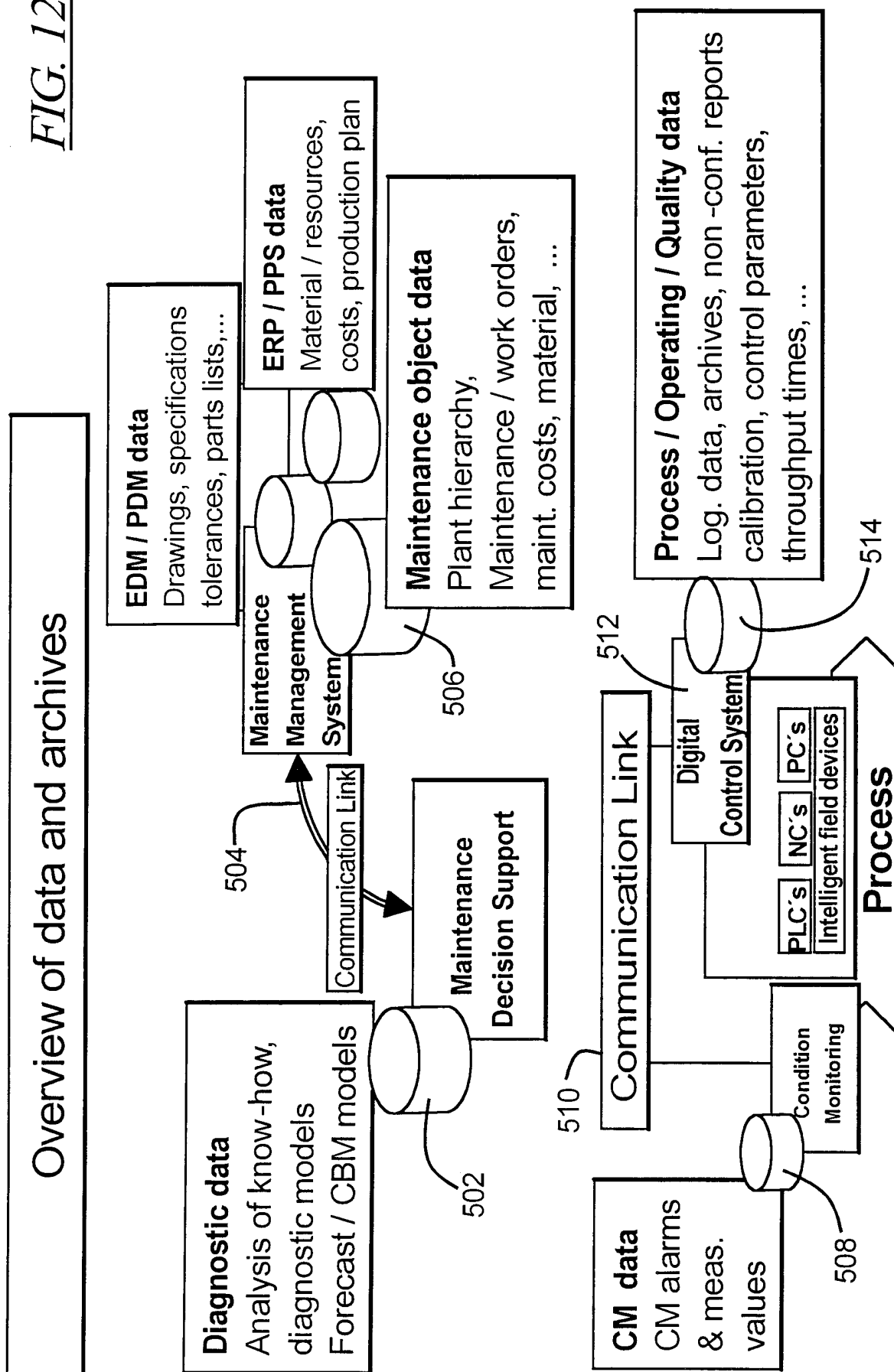


FIG. 12



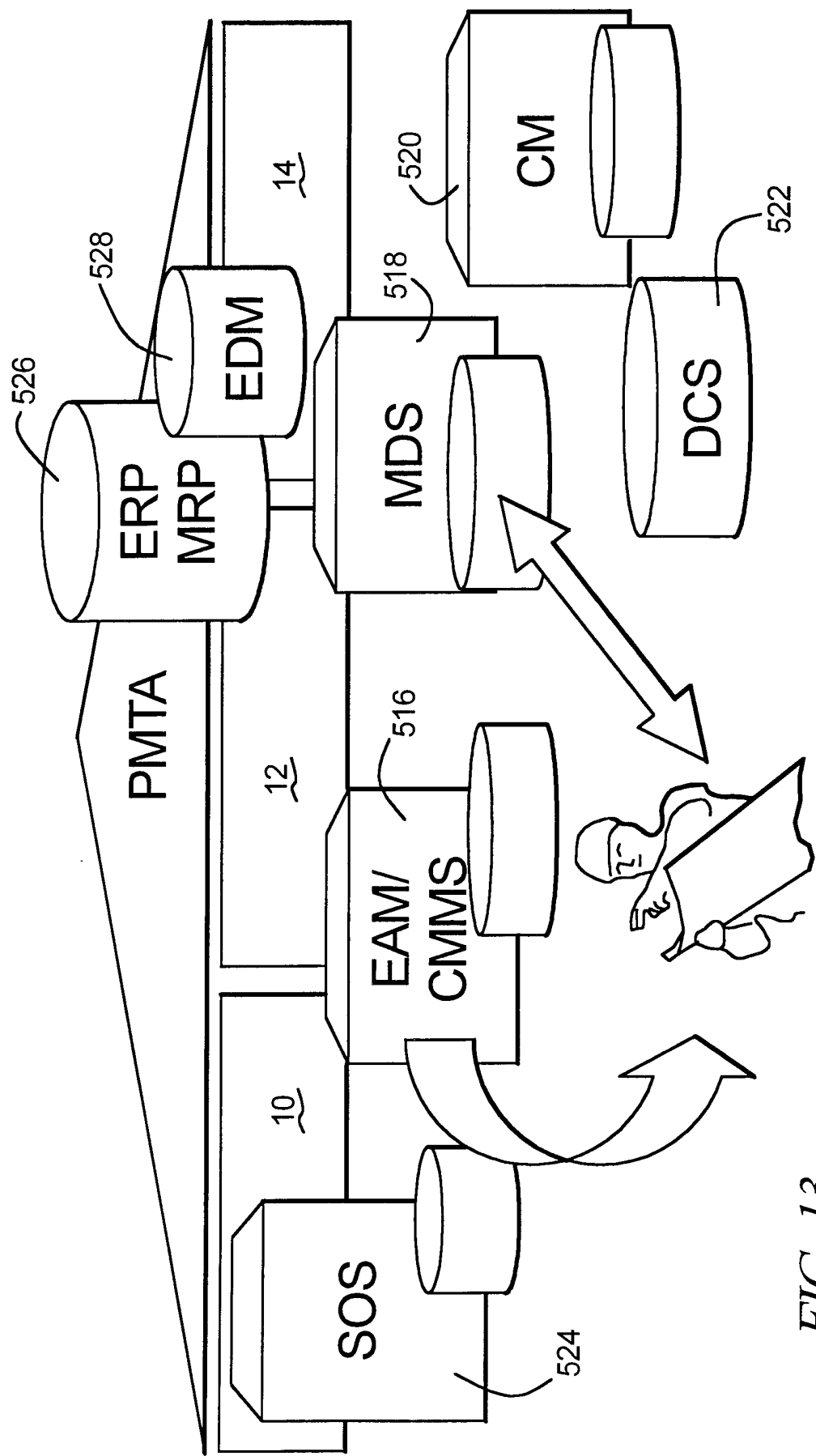


FIG. 13

FIG. 14

