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(54) **Steam turbine system.**

(57) Steam turbine system comprising an H.P. (high pressure) turbine unit (I), an I.P. (intermediate pressure) turbine unit (II), and a L.P. (low pressure) turbine unit (III), wherein the said turbine units are interconnected and the rotors of the H.P. turbine unit and of the I.P. turbine unit are coupled (13) with each other such that during normal operation they rotate at the same speed. According to the invention the L.P. turbine unit (III) comprises a group of a relatively large number of independent, relatively small L.P. turbines (T1, T2, T3 ... Tn) wherein each small L.P. turbine forms a set with a corresponding turbo- compressor (C1, C2, C3 ... Cn) and in each set the rotor of the small L.P. turbine is coupled (25), (26), (27), (28), with the rotor of the corresponding turbo-compressor such that, during normal operation, they rotate at the same speed. The steam inlet (31, 32, 33, 34) of each small L.P. turbine and the steam inlet (45, 46, 47, 48) of each corresponding turbo-compressor is connected to the steam outlet (9) of the I.P. turbine unit, and the steam outlet (35, 36, 37, 38) of each small L.P. turbine is connected to a steam exhaust. Furthermore the steam outlets (55, 56, 57, 58) of the turbo-compressors are connected to a suitable expansion stage of the H.P. or I.P. turbine unit and/or to other steam-consuming equipment. Finally the small L.P. turbines with the corresponding turbo-compressors are constructed in such a manner that during normal operation their rotors rotate at a substantially higher speed than the rotors of the H.P. and I.P. turbine units.

EP 0 081 272 A1

STEAM TURBINE SYSTEM

The invention relates to a steam turbine system comprising an H.P. (high pressure) turbine unit, an I.P. (intermediate pressure) turbine unit, and a L.P. (low pressure) turbine unit, wherein the steam inlet of the H.P. turbine unit is connected to a steam supply, the steam outlet of the H.P. turbine unit is connected to the steam inlet of the I.P. turbine unit, the steam outlet of the I.P. turbine unit is connected to the steam inlet of the L.P. turbine unit, the steam outlet of the L.P. turbine unit is connected to a steam exhaust, and wherein the rotors of the H.P. turbine unit and of the I.P. turbine unit are coupled with each other such that during normal operation they rotate at the same speed.

Such steam turbine systems are known. In a common type the H.P., I.P., and L.P. turbine units are coupled by means of a common shaft to a generator for generating electricity. In normal operation, therefore, the rotors of all the turbine units rotate at the same speed. A customary speed is 3000 r.p.m., whereby 600 MW is typically generated. These turbines usually employ a barrel-type H.P. turbine, one, or more usually two, diabolo I.P. turbines, and four diabolo L.P. turbines. The efficiencies of the various turbine units of such a steam turbine system tend to differ considerably. For example, in a very good turbine system with an overall efficiency of 0.86, the H.P. turbine unit might achieve an efficiency of 0.85, the I.P. turbine unit an efficiency of 0.9 or more, and the L.P. turbine an efficiency of 0.77 at the most. Also the costs per generated kW vary greatly from one turbine unit to the other.

Although the H.P. turbine unit is the most complex, since it must meet very exacting demands due to the high pressures and temperatures of the steam it receives; this is compensated however by the fact that the H.P. turbine unit has a very high power density on account of the condition of the steam it uses. The costs of the I.P. turbine unit per kW are, however, lower than those of the H.P. turbine unit. This is due to the fact that the pressures and temperatures of the steam used by the I.P. turbine unit are not extreme, so that the I.P. turbine unit can be constructively simple, the fact that in the I.P. turbine unit the increase in the steam's specific volume is moderate, and the fact that the I.P. turbine unit's efficiency is higher.

The dimensions of the L.P. turbine unit are very large due to the great volume increase of the steam in the L.P. turbine unit and to the restrictions placed on the speed of the steam owing to the rotational speed, material strength, and moisture content of the steam. The power density in the L.P. turbine unit is low on account of the great increase in the volume flow of the steam in the L.P. turbine unit for a comparable heat drop. Together with the low efficiency of the L.P. turbine unit, this results in the cost per generated kW being the highest for the L.P. turbine unit.

The above problems are caused by the customary L.P. turbine units having to process very large quantities of wet steam at forced speeds. The object of the invention is to eliminate these disadvantageous factors without detriment to the efficiency.

The above turbine system according to the invention is thereto characterized in that the L.P. turbine unit comprises a group of a relatively large number of independent, relatively small L.P. turbines, in that each small L.P. turbine forms a set with a corresponding turbo-compressor, in that in each set the rotor of the small L.P. turbine is coupled with the rotor of the corresponding turbo-compressor such that, during normal operation, they rotate at the same speed, in that the steam inlet of each small L.P. turbine and the steam inlet of each corresponding turbo-compressor is connected to the steam outlet of the I.P. turbine unit, in that the steam outlet of each small L.P. turbine is connected to a steam exhaust, and in that the steam outlets of the turbo-compressors are connected to a suitable expansion stage of the H.P. or I.P. turbine unit and/or to other steam-consuming equipment, the small L.P. turbines with the corresponding turbo-compressors being constructed such that during normal operation their rotors rotate at a substantially higher speed than the rotors of the H.P. and I.P. turbine units.

In the system according to the invention the exhaust steam from the I.P. turbine unit can be allowed to expand via the independant small L.P. turbines under optimum conditions, so that optimum efficiency is achieved. The speed of rotation of these small L.P. turbines can then adjust itself to the ideal flow conditions without control. In addition, the system according to the invention enables the mechanical energy produced by the small L.P. turbines to be used for driving the turbo-compressors in order to compress exhaust steam from the I.P. turbine unit to temperatures and pressures suitable for the steam conditions of one of the expansion stages of the H.P. or I.P. turbine units, so that the steam after compression can be fed to said expansion stage of the H.P. or I.P. turbine unit.

The said turbo-compressors can be cheap and compact if, according to the invention, they have at least two compression stages, an intercooler being connected between each pair of compression stages.

The energy efficiency of said compression can be boosted to 100% if the heat released by the intercooling is used for pre-heating boiler feedwater.

To this end, according to the invention the intercoolers are arranged such that they can serve to preheat the water for feeding the boiler of the steam turbine system.

In an advantageous embodiment of the steam turbine system according to the invention the small L.P. turbine and the corresponding turbo-compressor of each set have a common shaft.

The steam turbine system according to the invention will now be described with reference to the drawing.

A conventional turbine system of 600 MW, which during normal operation has a rotor speed of 3000 r.p.m., comprises an H.P. turbine unit with 7 expansion stages, an I.P. turbine unit also with 7 expansion stages, and an L.P. turbine unit with 5 expansion stages.

In the above-described conventional steam turbine system the heat drop in the L.P. turbine unit is very large, so that single-stage or two-stage compression of the exhaust steam of the I.P. turbine unit to an acceptable pressure for delivery to said expansion stage of the I.P. turbine unit is very difficult and/or unattractive. In the system according to the invention the first stage of the conventional L.P. turbine unit, which has a fairly high efficiency, is therefore added to the conventional I.P. turbine unit, giving an I.P. turbine unit with eight stages.

The drawing shows a supply conduit 1 for fresh steam at high pressure and temperature. Steam supplied by this conduit can pass via a reheater 2 and a conduit 3 to the steam inlet 4 of an H.P. turbine unit I. The turbine unit I is a conventional H.P. turbine with 7 expansion stages. After passing through the expansion stages of the H.P. turbine unit I, the steam leaves steam outlet 5 of the H.P. turbine unit I and flows via a conduit 6, reheater 2 and a conduit 7 to a steam inlet 8 of an I.P. turbine unit II. This I.P. turbine unit can be, for example, a "diabolo" turbine. As customary, this diabolo turbine is of symmetrical design and provided at each end with a steam outlet 9 from which steam having identical steam conditions leaves. The I.P. turbine unit II differs from conventional I.P. turbine units by having eight instead of seven expansion stages, i.e. each half of the diabolo turbine II has eight expansion stages, as stated above.

The rotors of the two turbine units I and II are fixed to a common shaft 13 so that the rotor speeds of the two turbine units I and II are equal during normal operation. This speed could be, for example, 3000 r.p.m. The shaft 13 drives, for example, a generator 14 for generating electricity.

The steam which, after passing through both the symmetrically arranged eight expansion stages of the I.P. turbine unit II, reaches the steam outlets 9, flows from the steam outlets 9 via conduits 10 and 11 to a conduit 12.

In the arrangement according to the invention the L.P. turbine unit III is formed by a group of a relatively large number of independent, relatively small L.P. turbines, which in the figure are indicated by T1, T2, T3 .... Tn. Although only four are shown in the drawing, this number is in fact much larger, for example 96. The diameter of the small L.P. turbines T1, T2, T3 ... Tn is considerably smaller than the diameter of the L.P. turbine unit of the conventional turbine system as described above. The operating speed of the small L.P. turbines T1, T2, T3 ... Tn is self-adjusting without control and is much higher than the operating speed of the H.P. and I.P. turbine units; for example about 10,000 r.p.m. The efficiency obtainable with these small L.P. turbines is more than 0.9.

The conduit 12 is connected via conduits 21, 22, 23 and 24 to steam inlets 31, 32, 33 and 34 respectively of the small L.P. turbines T1, T2, T3 and Tn respectively. The L.P. turbines T1, T2, T3 and Tn have steam outlets 35, 36, 37 and 38 respectively, which are connected via exhaust conduits 39, 40, 41 and 42 respectively to a condenser (not shown).

Turbine T1 and a corresponding turbo-compressor C1 have a common shaft 25; turbine T2 and a corresponding turbo-compressor C2 have a common shaft 26, turbine T3 and a corresponding turbo-compressor C3 have a common shaft 27, and turbine Tn and a corresponding turbo-compressor Cn have a common shaft 28. Steam inlets 45, 46, 47 and 48 of turbo-compressors C1, C2, C3 and Cn respectively are connected via supply conduits 49, 50, 51 and 52 respectively to the conduit 12.

Steam outlets 55, 56, 57 and 58 of the turbo-compressors C_1, C_2, C_3 and Cn are connected via steam exhaust conduits 60, 61, 62 and 63 respectively to a conduit 65. The conduit 65 is connected to a steam inlet 70 belonging to the fourth steam expansion stage of the I.P. turbine unit II.

The compressors C1, C2, C3 and Cn are provided with intercoolers 66, 67, 68 and 69 respectively which are arranged between the two compression stages of each compressor. These intercoolers 66, 67, 68 and 69 can, if desired, be used to preheat boiler feedwater.

As has been explained above, the outlet steam of the I.P. turbine unit is delivered to the conduit 12. From this conduit 12, it flows via the conduits 21, 22, 23 and 24 and the steam inlets 31, 32, 33 and 34 into the turbines T1, T2, T3 and Tn respectively. The steam expands in these turbines and finally flows via the steam outlets 35, 36, 37 and 38 and the exhaust conduits 39, 40, 41 and 42 respectively to the condenser (not shown).

The expansion of the steam in the turbines T1, T2, T3 and Tn causes rotation of the shafts 25, 26, 27 and 28 respectively, which drive the turbo-compressors C1, C2, C3 and Cn respectively.

Via the supply conduits 49, 50, 51 and 52 and the steam inlets 45, 46, 47 and 48 respectively the turbo-compressors suck steam from the conduit 12.

In each compressor C1, C2, C3 and Cn the steam is compressed in two compression stages, intercooling being applied between the stages with the aid of intercoolers 66, 67, 68 and 69 respectively. After the steam has been compressed in the compressors C1, C2, C3 and Cn, the compressed steam leaves the compressors via the steam outlets 55, 56, 57 and 58 respectively and flows via the conduits 60, 61, 62 and 63 respectively to the conduit 65.

By being compressed, the steam is brought into a condition corresponding with the condition of the steam entering the fourth steam expansion stage of the I.P. turbine unit II. The compressed steam is fed via the conduit 65 to the steam inlets 70a and 70b belonging to said expansion stage.

In the I.P. turbine unit II the compressed steam makes its contribution to the high-efficiency production of mechanical energy.

A big advantage of replacing the conventional large L.P. turbine unit by the described group of a large number of small L.P. turbines T1, T2, T3 ... Tn with corresponding compressors C1, C2, C3 ... Cn is that these machines are small and can thus be made relatively cheaply and in large production runs.

If desired, a number of the small L.P. turbines with their corresponding compressors can be switched out; or a part of the outlet steam of the I.P. turbine unit can be used for heating purposes. This makes a flexible control with high efficiency possible.

It should be pointed out that, if desired, the steam can also be compressed to such a degree in the said turbo-compressors that the compressed steam can be fed to a suitable expansion stage of the H.P. turbine unit I.

It is not strictly necessary to feed the steam compressed in the turbo-compressors to the H.P. or I.P. turbine units. At least a part of the compressed steam can, if desired, be fed to other steam-consuming equipment where it might be employed, for example, for heating or processing purposes.

Said sets, each comprising a small L.P. turbine and a corresponding turbo-compressor, preferably have substantially the same dimensions. This has the advantage that these sets can be made in large runs at relatively low costs.

In an advantageous embodiment of the system according to the invention at least some of said sets can be cut out. This enables one or more, as appropriate, of the sets to be cut off from the supply of exhaust steam from the I.P. turbine unit. The part of the steam from the I.P. turbine unit thus available can then be used for various other purposes, such as for heating and/or processing purposes.

The steam supplied to a small L.P. turbine and to the corresponding turbo-compressor of one or more of the said sets can, if desired, be expanded, respectively compressed to a pressure suitable for various purposes, such as for heating and/or processing purposes.

The small L.P. turbine and corresponding turbo-compressor of at least one of said sets is preferably constructed such that their rotors are mounted on a common shaft situated entirely within a housing such that there are no shaft passages through the walls of the housing.

The shaft of said set is preferably located in hydrostatic or hydrodynamic bearings which can be lubricated by steam.

Those skilled in the art will appreciate that although the steam turbine system according to the invention will normally be driven by steam, if desired, it may alternatively be driven by NH_3, freon, benzene or any other suitable fluid in the gaseous phase.

CLAIMS

1. Steam turbine system comprising an H.P. (high pressure) turbine unit, an I.P. (intermediate pressure) turbine unit, and a L.P. (low pressure) turbine unit, wherein the steam inlet of the H.P. turbine unit is connected to a steam supply, the steam outlet of the H.P. turbine unit is connected to the steam inlet of the I.P. turbine unit, the steam outlet of the I.P. turbine unit is connected to the steam inlet of the L.P. turbine unit, the steam outlet of the L.P. turbine unit is connected to a steam exhaust, and wherein the rotors of the H.P. turbine unit and of the I.P. turbine unit are coupled with each other such that during normal operation they rotate at the same speed, characterized in that the L.P. turbine unit comprises a group of a relatively large number of independent, relatively small L.P. turbines, in that each small L.P. turbine forms a set with a corresponding turbo-compressor, in that in each set the rotor of the small L.P. turbine is coupled with the rotor of the corresponding turbo-compressor such that, during normal operation, they rotate at the same speed, in that the steam inlet of each small L.P. turbine and the steam inlet of each corresponding turbo-compressor is connected to the steam outlet of the I.P. turbine unit, in that the steam outlet of each small L.P. turbine is connected to a steam exhaust, and in that the steam outlets of the turbo-compressors are connected to a suitable expansion stage of the H.P. or I.P. turbine unit and/or to other steam-consuming equipment, the small L.P. turbines with corresponding turbo-compressors being constructed such that during normal operation their rotors rotate at a substantially higher speed than the rotors of the H.P. and I.P. turbine units.

2. Steam turbine system according to claim 1, characterized in that the small L.P. turbines with the corresponding turbo-compressors of each set are arranged such that during normal operation their rotors rotate at speeds which, freely and without control, can adjust themselves in a stable manner.

3. Steam turbine system according to any one of the claims 1 and 2, characterized in that the said sets have substantially the same dimensions.

4. Steam turbine system according to any one of the claims 1-3, characterized in that said turbo-compressors have at least two compression stages, an intercooler being arranged between each pair of compression stages.

5. Steam turbine system according to claim 4, characterized in that the intercoolers are arranged such that they can serve to preheat the water for feeding the boiler of the steam turbine system.

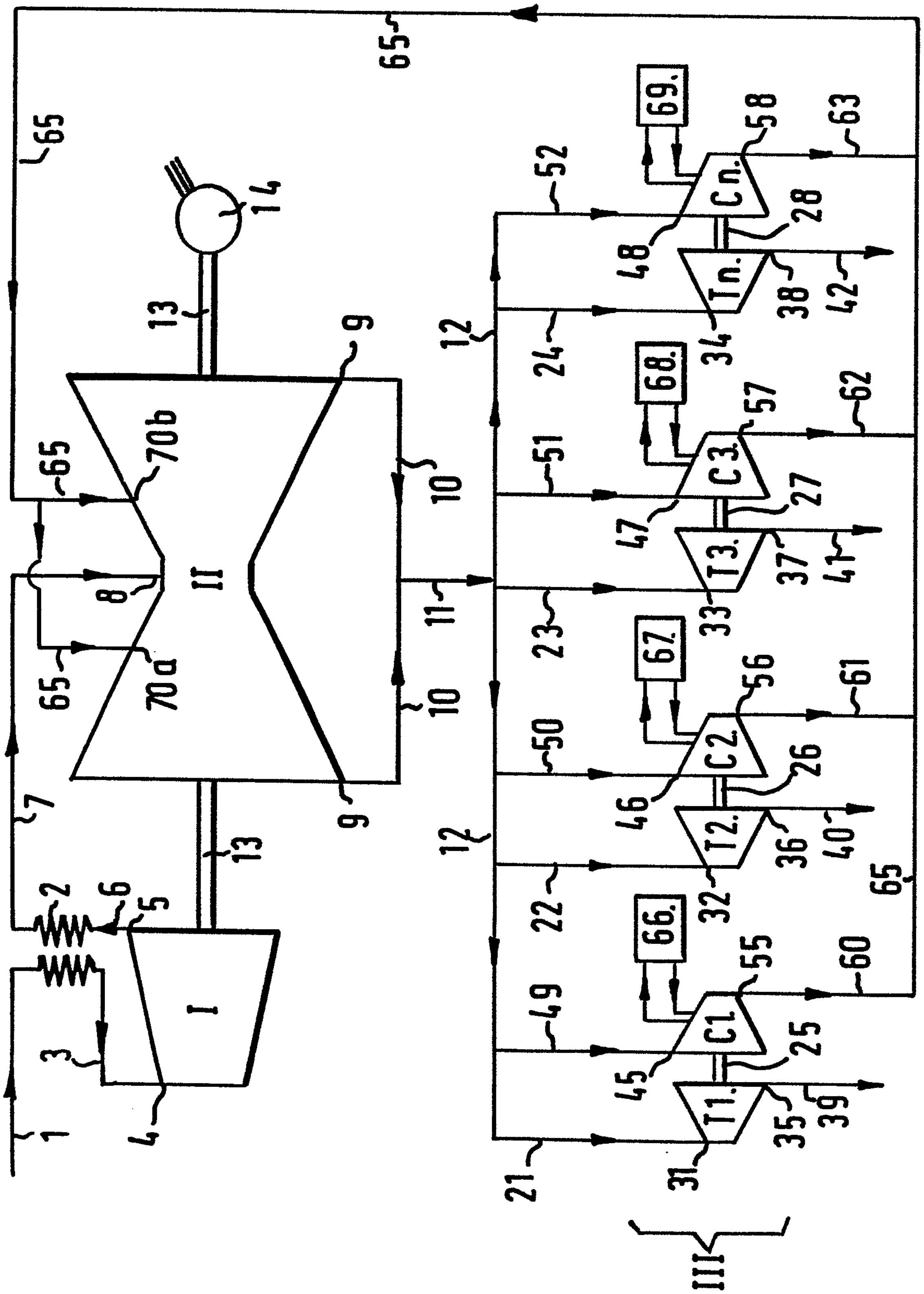
6. Steam turbine system according to any one of the claims 1-5, characterized in that the small L.P. turbine and the corresponding turbo-compressor of each set have a common shaft.

7. Steam turbine system according to any one of the claims 1-6, characterized in that at least some of said sets can be cut out such that an adjustable part of the I.P. outlet steam can be made available for various purposes (e.g. for heating and/or processing purposes).

8. Steam turbine system according to any one of the claims 1-7, characterized in that it is designed such that the steam supplied to a small L.P. turbine and to the corresponding turbo-compressor of one or more sets can therein be expanded, respectively compressed to a pressure suitable for various purposes, such as for heating and/or processing purposes.

9. Steam turbine system according to any one of the claims 1-8, characterized in that the small L.P. turbine and the corresponding turbo-compressor of at least one of said sets are constructed such that their rotors are mounted on a common shaft situated entirely within a housing such that there are no shaft passages through the walls of the housing.

10. Steam turbine system according to claim 9, characterized in that the shaft of said set is located in hydrostatic or hydrodynamic bearings which can be lubricated by steam.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EUROPEAN SEARCH REPORT

0081272
Application number
EP 82 20 1548

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	GB-A- 222 126 (ERSTE BRÜNNER MASCH.) *Page 1, lines 21-56, line 91 to page 2, line 2* ---	1,7	F 01 D 13/00 F 10 K 19/04
A	DE-C- 491 391 (MAFFEI A.G.) *Page 1, lines 17-19,31-45, line 55 to page 2, line 3* ---	1,7	
A	NL-C- 37 761 (STORK & CO. N.V.) *Page 2, lines 9-11* ---	1	
A	DE-C- 221 247 (SAUER) *Page 1, lines 53-58; page 2, lines 11-16* ---	4	**TECHNICAL FIELDS SEARCHED (Int. Cl. 3)**
A	ATOMKERNENERGIE (ATKE), vol. 2, no. 14, April 1969, pages 118-24; F.ERBACHER et al.: "Zur Entwicklung von Dampfgebläsen für dampfgekühlte schnelle Brutreaktoren". *Page 118, figure 1; page 119, right-hand column, last paragraph to page 120, left-hand column, first pragraph; page 121, right-hand column, last paragraph* --- -/-	2,6,9, 10	F 01 D F 01 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04-03-1983	DELL W.H.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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EUROPEAN SEARCH REPORT

Application number

EP 82 20 1548

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	US-A-3 568 444 (HARRIS) *Column 3, line 74 to column 4, line 30; figure 3*		
A	CH-A- 351 980 (METROPOLITAN-VICKERS) *Page 2, lines 55-64*		
A	NL-A-7 510 201 (NUMAN)		

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

The present search report has been drawn up for all claims

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THE HAGUE	04-03-1983	DELL W.H.

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X : particularly relevant if taken alone
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A : technological background
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