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[Continued on next page]

(54) Title: ELECTRIC MACHINE WITH DAMPENING MEANS

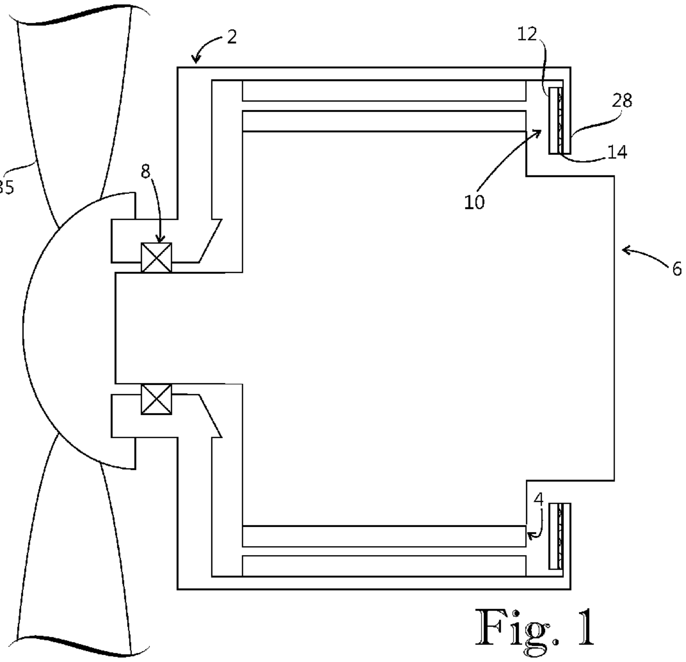

Fig. 1

(57) Abstract: An electric machine comprising a support frame (6), an outer rotor (2), a stator (4), and dampening means, the outer rotor (2) and the stator (4) being supported to the support frame (6), the dampening means being adapted for dampening vibrations of the outer rotor. The outer rotor (2) comprises an annular end plate (28), the dampening means comprises a first damper (10; 10'; ") having a first constraint element (12; 12'; 12")and a first visco-elastic layer (14; 14'; 14") provided on a surface of the first constraint element (12; 12'; 2"), the first constraint element (12; 12'; 12") being connected to the annular end plate (28) through the first visco-elastic layer (14; 14'; 14").

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ELECTRIC MACHINE WITH DAMPENING MEANS

FIELD OF THE INVENTION

The present invention relates to suppression of vibrations in a rotating electric machine.

Vibrations of a rotating electric machine may have several different sources such as unbalance in a rotor, magnetic forces due to imperfect magnetic design, external excitation, or magnetic forces caused by air-gap anomalies due to overhang of an outer rotor of the rotating electric machine combined with gravitational pull.

Vibrations cause significant problems in known rotating electric machines. Vibrations may cause excessive noise. Vibrations may also shorten operating life of rotating electric machines.

BACKGROUND OF THE INVENTION

The invention utilizes a constrained-layer damping technique which is described for example in following documents.

[1] Cremer, L. & Heckl, M. & Ungar, E.E., 1987. Structure-Borne Sound. 2nd ed. Berlin: Springer Verlag.

[2] Ewins, D.J., 2001. Modal Testing, Theory, Practice, and Application. 2nd ed. Hertfordshire, England: Research Studies Press ltd.

[3] Garibaldi, L. & Onah, H.N., 1996. Viscoelastic Material Damping Technology. Torino: Becchis Osiride.

There exist a great number of mathematical formulations to describe the dampening mechanisms of a material. Herein, a hysteretical damping model is used. The hysteretical damping model is also called as a structural damping model. For hysteretically damped isotropic material, the complex Young's modulus E* and Shear modulus G* are defined as

$$E^*=E(1+j\eta)$$

$$G^*=G(1+j\eta),$$

where E is the real Young's modulus, G is the real shear modulus and η is the material loss factor. Above definitions can be found in reference [3], on page 30.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to provide an outer rotor electric machine so as to alleviate the above vibration problems. The object of the invention is achieved by an electric machine which is characterized by what is stated in the independent claim 1. The preferred embodiments of the invention are disclosed in the dependent claims.

The invention is based on the idea of providing an outer rotor of an electric machine with one or more dampers connected to an annular end plate of the outer rotor, the one or more dampers utilizing constrained-layer damping technique.

An advantage of the invention is that vibrations of an outer rotor electric machine may be suppressed thereby reducing noise and extending the operating life of the electric machine.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which

Figure 1 shows a cross section of an electric machine according to an embodiment of the present invention;

Figure 2A shows dampening means of the electric machine of Figure 1;

Figure 2B shows dampening means of an electric machine according to further embodiment of the present invention; and

Figure 2C shows dampening means of an electric machine according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows an electric machine comprising a support frame 6, an outer rotor 2, a stator 4, and dampening means. The outer rotor 2 and the stator 4 are supported to the support frame 6. The stator 4 is immovably supported to the support frame 6 whereas the outer rotor 2 is rotatably supported to the support frame 6. The dampening means is adapted for dampening vibrations of the outer rotor. Herein an outer rotor refers to a rotor that is located radially farther from centre line of an electric machine than the stator of the electric machine.

Figure 2A is an enlargement showing dampening means of the electric machine of Figure 1. The dampening means comprises a first damper 10 having a first constraint element 12 and a first visco-elastic layer 14 provided on a surface of the first constraint element 12, the first constraint element 12 being connected to the outer rotor through the first visco-elastic layer 14. The first damper 10 is adapted for damping radial vibrations of the outer rotor 2. The first constraint element 12 is a monolithic element having a form of an annular ring. Also the first visco-elastic layer 14 has a form of an annular ring. The first constraint element 12 may be manufactured from steel or aluminium, for example. In embodiments where it is not possible to construct a first constraint element as a monolithic element, the parts of the first constraint element should be joined together rigidly.

The outer rotor 2 comprises an annular end plate 28, the first damper 10 being connected to the annular end plate 28. The annular end plate 28 may be made of steel or aluminium. A symmetry axis of the annular end plate 28 coincides with rotation axis of the outer rotor 2. Thus a plane defined by the annular end plate 28 extends perpendicular to the rotation axis of outer rotor 2.

The outer rotor 2 is supported to the support frame 6 exclusively at one end by a bearing 8 located at an opposed end of the outer rotor 2 relative to the annular end plate 28. The bearing 8 may comprise one or more bearing units. A bearing unit may comprise for example a ball bearing or a cylindrical bearing.

The annular end plate 28 and the bearing 8 are spaced apart in axial direction of the outer rotor machine. Active parts of the outer rotor 2 and the stator 4 are situated between the annular end plate 28 and the bearing 8 when seen in the axial direction, the active parts being the components adapted to interact magnetically during operation of the machine.

The proper design method, also known as Master Curve Procedure using International Plot, for optimizing the damping capacity vs. temperature and frequency is explained thoroughly in reference [3], on pages 101-110. The reference [3], which is identified in section Background of the Invention, discloses that the material loss factor has a property of reaching a maximum value at certain temperature and frequency. In other words the material loss factor is a function on temperature and frequency.

To ensure an adequate damping capacity of the first damper 10 maximum loss factor η_{fvel_max} of the first visco-elastic layer 14 is greater than or equal to 0,7. Both the maximum loss factor η_{fce_max} of the first constraint element 12 and the maximum loss factor η_{vpc_max} of the outer rotor 2 are substantially less than the maximum loss factor η_{fvel_max} of the first visco-elastic layer 14.

In an alternative embodiment maximum loss factor of the first visco-elastic layer is greater than or equal to 0,9. Basically, the higher the maximum loss factor of a visco-elastic layer is the more effective the damping is.

In the embodiment shown in Figure 1 the outer rotor 2 is a one-piece component, the annular end plate 28 being an integral part of the outer rotor 2. The first constraint element 12 is connected to the outer rotor 2 exclusively through the first visco-elastic layer 14. There are no bolts, screws or other stiff particles connecting the first constraint element 12 to the outer rotor 2. The first visco-elastic layer 14 is a one-piece layer.

Figure 2B shows dampening means of an electric machine according to further embodiment of the present invention. In Figure 2B the outer rotor comprises a first portion 271' and a second portion 272', the first damper 10' being located between the first portion 271' of the outer rotor and the second portion 272' of the outer rotor such that the first damper 10' separates the first portion 271' of the outer rotor from the second portion 272' of the outer rotor, the second portion 272' of the outer rotor being connected to the first constraint element 12' through the first visco-elastic layer 14'. The first portion 271' of the outer rotor comprises a cylindrical body. The first constraint element 12' is joined rigidly to the first portion 271' of the outer rotor for example by welding or by screws. Alternatively the first constraint element 12' may be an integral part of the first portion 271' of the outer rotor. The second portion 272' of the outer rotor comprises an annular end plate 28'.

Figure 2C shows dampening means of an electric machine according to another embodiment of the present invention. The dampening means of Figure 2C comprises a first damper 10" and a second damper 20" connected to an annular end plate 28" of an outer rotor. The first damper 10" includes a first constraint element 12" and a first visco-elastic layer 14" provided on a surface of the first constraint element 12", the first constraint element 12" being connected to the annular end plate 28" through the first visco-elastic layer 14". The second damper 20" comprises a second constraint element 22" and a second visco-elastic layer 24" provided on a surface of the second constraint element 22'', the second constraint element 22'' being connected to the outer rotor through the second visco-elastic layer 24''. Both the first constraint element 12'' and the second constraint element 22'' are substantially annular components. The annular end plate 28'' is sandwiched between the first damper 10'' and the second damper 20''.

Both the maximum loss factor η_{fvel-2_max} of the first visco-elastic layer 14'' and the maximum loss factor η_{svel-2_max} of the second visco-elastic layer 24'' are greater than or equal to 0,7. The maximum loss factor η_{fce-2_max} of the first constraint element 12'', the maximum loss factor η_{sce-2} of the second constraint element 22'' and the maximum loss factor η_{vpc-2_max} of the outer rotor each are substantially less than 0,7.

The first damper 10'' is optimized for a first temperature T_1 and a first frequency f_1. The second damper 20'' is optimized for a second temperature T_2 and a second frequency f_2. The second temperature T_2 is different from the first temperature T_1, and the second frequency f_2 is different from the first frequency f_1. Herein a damper is considered to be optimized for a certain temperature and a certain frequency if the material loss factor of the visco-elastic layer of the damper reaches its maximum value at said temperature and frequency.

Dampening means comprising a plurality of dampers may be configured such that each of the dampers is optimized for a different temperature-frequency pair than rest of the dampers. Thereby maximum dampening range of the dampening means may be widened.

In the embodiment of Figure 1 the outer rotor electric machine is configured as an electric generator of a wind power plant. The outer rotor 2 is adapted to be in direct contact with the surrounding air. Blades 35 of wind turbine are located at the same end of the outer rotor 2 as the bearing 8. In Figure 1 the blades 35 are depicted only partially. In an alternative embodiment an electric machine according to present invention is configured as a belt-roller motor adapted to be used in heavy steel industry.

An annular end plate of an outer rotor of a wind generator may be equipped with a brake disc for braking the outer rotor. The first damper may be located outer in radial direction than the brake disc. In some cases it is possible to retrofit a first damper according to present invention to an annular end plate of an outer rotor of an existing wind generator.

It will be obvious to a person skilled in the art that the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

CLAIMS

1. An electric machine comprising a support frame (6), an outer rotor (2), a stator (4), and dampening means, the outer rotor (2) and the stator (4) being supported to the support frame (6), the dampening means being adapted for dampening vibrations of the outer rotor, **characterized** in that the outer rotor (2) comprises an annular end plate (28), the dampening means comprises a first damper (10; 10'; 10") having a first constraint element (12; 12'; 12") and a first visco-elastic layer (14; 14'; 14") provided on a surface of the first constraint element (12; 12'; 12"), the first constraint element (12; 12'; 12") being connected to the annular end plate (28) through the first visco-elastic layer (14; 14'; 14").

2. An electric machine according to claim 1, **characterized** in that the outer rotor (2) is supported to the support frame (6) exclusively at one end by a bearing (8) located at an opposed end of the outer rotor (2) relative to the annular end plate (28).

3. An electric machine according to claim 1 or 2, **characterized** in that the maximum loss factor (η_{fvel_max}) of the first visco-elastic layer (14; 14'; 14") is greater than or equal to 0,7.

4. An electric machine as claimed in claim 1, 2 or 3, **characterized** in that the maximum loss factor (η_{fce_max}) of the first constraint element (12; 12'; 12") is substantially less than the maximum loss factor (η_{fvel_max}) of the first visco-elastic layer (14; 14'; 14").

5. An electric machine as claimed in any one of the preceding claims, **characterized** in that the maximum loss factor (η_{vpc_max}) of the outer rotor is substantially less than the maximum loss factor (η_{fvel_max}) of the first visco-elastic layer (14; 14'; 14").

6. An electric machine as claimed in any one of the preceding claims, **characterized** in that the first constraint element (12; 12'; 12") is a monolithic element.

7. An electric machine as claimed in any one of the preceding claims, **characterized** in that the first constraint element (12; 12") is connected to the outer rotor exclusively through the first visco-elastic layer (14; 14").

8. An electric machine as claimed in any one of claims 1 to 6, **characterized** in that the outer rotor comprises a first portion (271') and

a second portion (272'), the first damper (10') being located between the first portion (271') of the outer rotor and the second portion (272') of the outer rotor such that the first damper (10') separates the first portion (271') of the outer rotor from the second portion (272') of the outer rotor, the second portion (272') of the outer rotor being connected to the first constraint element (12') through the first visco-elastic layer (14').

9. An electric machine as claimed in any one of the preceding claims, **characterized** in that the dampening means further comprises a second damper (20") having a second constraint element (22") and a second visco-elastic layer (24") provided on a surface of the second constraint element (22"), the second constraint element (22") being connected to the outer rotor through the second visco-elastic layer (24").

10. An electric machine according to claim 9, **characterized** in that the first damper (10") is optimized for a first temperature (T_1) and a first frequency (f_1), and the second damper (20") is optimized for a second temperature (T_2) and a second frequency (f_2), the second temperature (T_2) being different from the first temperature (T_1), and the second frequency (f_2) being different from the first frequency (f_1).

11. A wind power plant for converting wind energy into electric energy, the wind power plant comprising an electric generator, **characterized** in that the electric generator is an electric machine according to any one of claims 1 to 10.

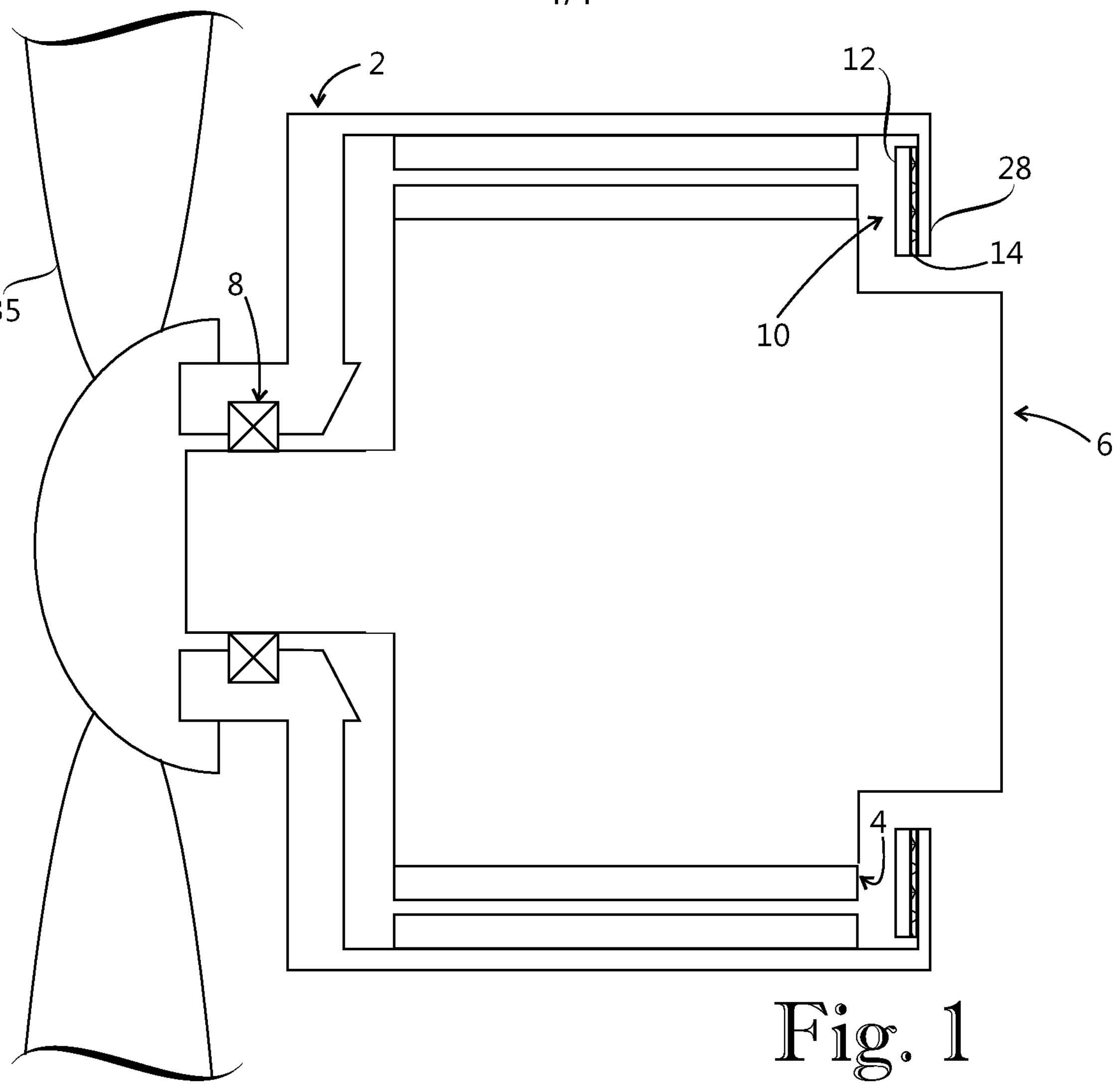

Fig. 1

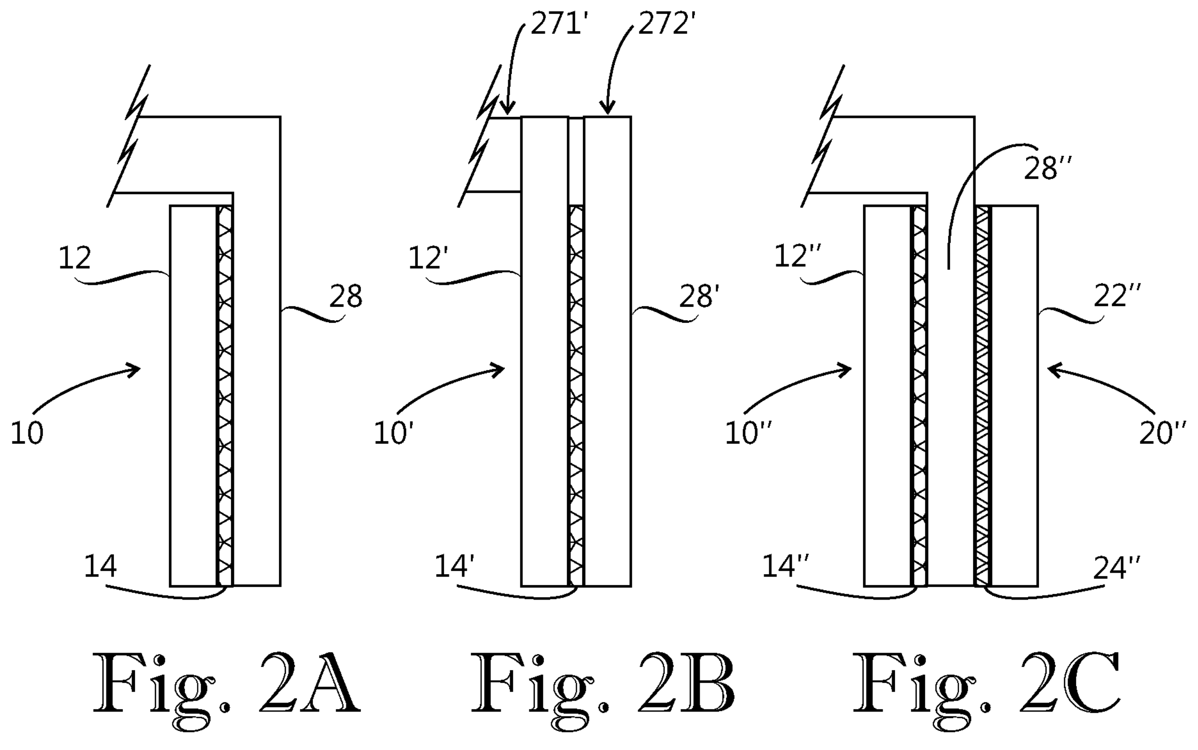

Fig. 2A Fig. 2B Fig. 2C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2012/050989

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H02K, F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 7059315 A (SHIBAURA ENG WORKS LTD) 03 March 1995 (03.03.1995) abstract [online] EPOQUENET EPODOC & WPI, and figures	1 - 11
X	US 2004207274 A1 (EWERT A. et al.) 21 October 2004 (21.10.2004) abstract, paragraphs 0003 – 0007, claims, and figures	1 - 11
X	US 4617484 A (BUIJSEN J.) 14 October 1986 (14.10.1986) abstract, column 2 lines 53 – 56, claims, and figures	1 - 11
X	US 2945138 A (STRANG C.) 12 July 1960 (12.07.1960) column 2 lines 17 – 32, claims, and figures	1 - 11
X	US 3527969 A (PAPST H.) 08 September 1970 (08.09.1970) abstract [online] EPOQUENET EPODOC & WPI, claims, and figures	1 - 11

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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- "&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2393586 A (AUTOMOTIVE MOTION TECH LTD) 31 March 2004 (31.03.2004) abstract, page 6 second paragraph, claims, and figures	1 - 11
A	JP 2010011686 A (MITSUBA CORP) 14 January 2010 (14.01.2010) abstract [online] EPOQUENET EPODOC & WPI, and figures	1 - 11
A	KR 100718164 B1 (KUMHO IND CO LTD et al.) 08 May 2007 (08.05.2007) abstract [online] EPOQUENET EPODOC & WPI, and figures	1 - 11

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CLASSIFICATION OF SUBJECT MATTER

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