

"Supervisory operation control system for protecting elevators or the like from a dangerous situation".

1 The present invention relates to a supervisory
control system for elevators or lifts, various railway
equipments, power plants inclusive of nuclear plants,
plant equipments for chemical industries and the like.
5 More particularly, the invention concerns a supervisory
operation control system which can assure reliable
supervisory operations conforming to actually prevailing
situations upon occurrence of an earthquake or the like
abnormal events.

10 In the elevator systems, various railways,
power plant of large capacity or other various plant
equipments, occurrence of an earthquake in the course of
operation of these plants results in that the plant
facilities are subjected to intensive shaking or vibra-
15 tion, involving occurrence of abnormalities in the faci-
lities which may bring about dangerous situations.

 Accordingly, it is desirable that upon
appearance of vibration due to the earthquake or the
like events in a predetermined place or location such as
20 buildings in which various equipments or facilities are
housed or the sites of the buildings or plants, control
of the operations of the plants or equipments is put
into effect as early as possible so that occurrence of
abnormalities due to the vibration will not involve a

1 dangerous situation in the operations of the plants or
equipments. The operation of this sort may be referred
to as the supervisory operation and the control for
effecting the supervisory operation is referred to as
5 the supervisory operation control.

By way of example, in the case of an elevator
or lift system which is installed in a building, the
elevator car or cage carrying passengers will stop at
other positions than the predetermined landing place when an
10 abnormality intervenes in the running function or per-
formance of the elevator or lift car because of swinging
or shaking of the building due to the earthquake or
strong winds, as the result of which the passengers are
confined within the car. Accordingly, the supervisory
15 operation control capability is of great utility in
order to prevent the dangerous situation and assure
restoration of the elevator system to the normal opera-
tion as soon as possible when the shaking is mitigated
or settled. Such being the circumstances, there exists
20 an increasing tendency to adopt the supervisory opera-
tion control in the elevator or lift systems.

For performing the supervisory operation
control, it is necessary to detect the generation of
vibration (or shaking) in the building in which the ele-
25 vator system is installed. To this end, it is required
to install a seismometer, which is commonly installed in
a machine room of the elevator system so as to detect

- 1 acceleration making appearance on the floor of the
machine room. When the sensed acceleration exceeds pre-
determined reference levels or values listed exemplarily
in the following table 1, signals for triggering the
5 supervisory operation are generated.

Table 1

Type of elevator	Reference value set for a single grade or lower one of reference values set for two grades (generation of supervisory operation signal Y)	Higher one of reference values set for two grades (genera- tion of super- visory operation signal R)
Ordinary elevator	80 Gal	_____
Elevator provided with express zone	80 Gal	150 Gal
Elevator for emergency	80 Gal	150 Gal

- As will be seen in the table 1, in the case of
the elevator system having an express zone, the seismo-
meter for detecting the vibration of a first intensity
grade is operated to generate a supervisory operation
10 signal Y when the seismic acceleration exceeds 80 Gal,
while the seismometer set for detecting the vibration of
a second intensity grade produces a supervisory opera-

1 tion signal R when the seismic acceleration exceeds 150
Gal, wherein these signals Y and R are transmitted to
the elevator control system for putting into effect the
supervisory operation.

5 According to a hitherto known typical super-
visory operation, the elevator car is stopped at the
nearest landing floor to allow the passengers to get off
the car by opening the door and subsequently the car
operation is set at rest, when only the seismometer set
10 for the first intensity grade operates to generate the
supervisory operation signal Y. On the other hand, when
the seismometer set for the second intensity grade also
operates to produce the supervisory operation signal R,
the car is instantly stopped and the signal R is also
15 transmitted to a supervisor room to inform the super-
visor of the emergency stopping of the car. Then, the car
is operated at a low speed to the nearest floor if the
situation permits, and the passengers are allowed to get
off through the opened door. Thereafter, the car opera-
20 tion is stopped with the door being closed, waiting for
the arrival of maintenance or service engineers.

According to another example of the hitherto
known supervisory elevator operation, upon operation of
only the seismometer set for the first intensity grade
25 of vibration and hence generation of only the signal Y,
the elevator car is stopped at the nearest landing floor
to open the door for allowing the passengers to get off

1 the car, which is followed by the closing of the door.
When the earthquake is settled or mitigated after a time
lapse and the signal Y produced by the seismometer set
for the first grade of seismic intensity disappears, the
5 elevator system is automatically restored to the normal
operation. However, in case the seismometer set for the
second grade of intensity operates to produce the signal
R, emergency stopping of the elevator car takes place as in
the case of the first mentioned supervisory control of
10 the prior art. In this connection, it should be men-
tioned that measures against the seismic vibration
should be provided to an adequate extent so that the
elevator can be normally operated without failure even
under seismic vibration of such a great amplitude which
15 causes the seismometer set for the second grade of
intensity to be actuated.

In the case of the earthquake or typhoon of a
large size, there is a possibility that a large number
of elevator systems should fail in a particular
20 district. For restoring the failed elevators at the
earliest convenience, many service engineers must be
summoned, which is difficult in actuality. Accordingly,
it is desirable to adopt the automatic restoring system
such as described in conjunction with the first men-
25 tioned supervisory elevator operation of the prior art.

By the way, either in the first or second men-
tioned supervisory elevator operations of the prior art

1 described above, the supervisory operation signals Y and
R produced by the seismometers set for the first and
second grades of the seismic intensity should represent
appropriately the degree of influence of the earthquake
5 affecting the machines and instruments of the elevator
system.

The degree or extent of the influence of
earthquake which affects the buildings inclusive of the
instruments, machines and other facilities can be esti-
10 mated on the basis of the steps or grades of seismic
intensity stipulated by the Japan Meteorological Agency
and summarized in the following table 2 in which the
seismic or vibrational accelerations equivalent to the
seismic intensity grades as adopted commonly heretofore
15 are also listed in the rightmost column.

Table 2

Grades of Intensity	Description	Equivalent acceleration
Not felt or intensity 0	Not felt by person but can be recorded by a seismometer	0 - 0.8 Gal
Slight or intensity I	Felt by persons at rest or sensitive persons	0.8 - 2.5 Gal
Weak or intensity II	Felt by many persons. Windows and doors rattle only slightly	2.5 - 8.0 Gal

... to be cont'd.

Rather strong or intensity III	Buildings swing. Windows and doors rattle appreciably. Hanging objects swing considerably. Surface of liquid in container disturbed.	8.0 - 25.0 Gal
Strong or intensity IV	Buildings swing intensively. Small objects are displaced or upset. Liquids spilled. Felt outdoors. Many frightened and run outdoors.	25.0 - 80.0 Gal
Very strong or intensity V	Wall cracked. Grave-stones and stone lanterns fallen. Chimneys and masonry damaged.	80.0 - 250.0 Gal
Disastrous or intensity VI	Less than 30 % of buildings destroyed. Landslides and cracks in ground. Difficult to stand.	250.0 - 400.0 Gal
Very disastrous or intensity VII	More than 30 % of buildings destroyed. Landslides, cracks in ground and faults.	Higher than 400.0 Gal

1 Heretofore, the supervisory signal Y is
generated when the seismic intensity is in the range of,
for example, 80 Gal - 150 Gal while the signal R is pro-
duced when the seismic intensity exceeds 150 Gal, by
5 making reference to the data such as listed in the table
2. However, actual application of the supervisory
operation control of this types to elevator systems has

1 encountered some troubles, which will be explained
below.

In the following table 3, there are listed
vibrations measured in a certain very high building upon
5 occurrence of earthquake of a large size in a distant
region.

Table 3

	Underground Room	Machine Room	Ratio
Maximum Acceleration (Half Amplitude)	2.5 Gal	15 Gal	6.0
Maximum Displacement (Half Amplitude)	55 mm	130 mm	2.4
Frequency	0.1 Hz	0.2 Hz	2.0

As will be seen from the table 3, the acce-
leration observed in the underground room is 2.5 Gal,
which corresponds to the seismic intensity I in the
10 table 2 when considered in terms of the equivalent acce-
leration. In contrast, in the machine room standing on
the uppermost floor of the building, the acceleration is
amplified to 15 Gal which corresponds to the intensity
grade III when considered in terms of the equivalent
15 acceleration. The elevator will not be subjected to any
damage at the seismic intensity of this grade. In

1 reality, neither the seismometer responded nor the
supervisory signal was generated.

However, since the frequency was as low as 0.2
Hz, displacement of great value (e.g. 130 mm in half
5 amplitude) occurred, giving rise to considerable swinging
or shaking of the building which was accompanied by a
great accident that the signal cable communicating the
elevator car with the machine room was broken.

In light of the lesson drawn from the hap-
10 pening mentioned above, the level of acceleration at
which the supervisory signal is generated was therefore
lowered to 30 Gal. Although this value is inadequate
because no supervisory signal will be generated in the
situation described above, another problem will be
15 encountered if the acceleration level is further
lowered.

Later on, upon occurrence of an earthquake of a
small size in a near region, vibration listed in the
following table 4 was observed in the same building.

Table 4

	Underground Room	Machine Room	Ratio
Maximum Acceleration (Half Amplitude)	13 Gal	30 Gal	2.3
Maximum Displacement (Half Amplitude)	3 mm	10 mm	3.3
Frequency	1 Hz	1 Hz	1

1 In the case of the earthquake under con-
sideration, the acceleration of 13 Gal observed in the
underground room was amplified to 30 Gal in the machine
room, resulting in that the supervisory signal Y was
5 generated, being accompanied with the stoppage of all
the elevator cars at the nearest floors. The elevator
cars were at rest about ten minutes after the stoppage.

 In this connection, it should be noted that
the frequency was 1 Hz and that the displacement was as
10 small as 1 cm in half amplitude, which means that the
seismic intensity applied to the building is of such
magnitude that the stoppage of the cars is unne-
cessary. Notwithstanding, the cars were stopped, giving
much trouble to the passengers.

20 As will be understood from the exemplary cases
described above, it is doubtful whether there exists a

1 definite relationship between the seismic acceleration
and the intensity grade which has been believed to have
bearing on the influence affecting the indoor facilities
inclusive of the elevator system. This question has
5 heretofore been pointed out in several articles. Among
them, the typical one is Takagi's article contained in
Meteorological Study Reports, Vol. 20, No. 1, p.p. 78-89
(1969).

Fig. 1 of the accompanying drawings graphi-
10 cally illustrates the actually measured relationship
between the seismic intensity grade and the accelera-
tion, in which solid line segments represent the equiva-
lent accelerations listed in the table 2 and the points
in black represent the relation between the seismic
15 intensities and the accelerations. As will be seen in
Fig. 1, acceleration of 180 Gal is observed at the
seismic intensity grade V. Although the acceleration is
valid for the equivalent acceleration in the table 2, it
has been found that the acceleration of the same magnitude
20 is observed at the intensity grade II. This means that
no specific correspondence or relationship exists bet-
ween the seismic intensity grades and accelerations.
Accordingly, an error will be involved if a correspon-
dence is established between the seismic intensity gra-
25 des and accelerations as indicated in the table 2.

As will now be understood from the above ana-
lyses, the hitherto known supervisory operation control

1 system is disadvantageous in that the conditions which
allow the entry to the supervisory operation have no
bearing on the strong swinging actually felt and
possibly bringing about abnormalities in the operations
5 of facilities, thus making it impossible to conduct
the supervisory operation under the desired conditions
with high reliability and accuracy. The foregoing
description has been made particularly in conjunction
with the elevator system. However, the description is
10 also relevant in the case of various railway equipments,
nuclear power plants, chemical industry plants, facilities
for transporting heavy articles and the like.
Difficulty has been encountered in carrying out the
supervisory operation in conformance with the actual
15 seismic intensity with any reasonable reliability, whenever
the situation requires.

An object of the present invention is to provide a supervisory operation control system which is
immune to the drawbacks of the prior art described above
20 and capable of performing satisfactorily without fail
the supervisory operation of facilities such as an elevator
system and the like in conformance with the actually
felt swinging or shaking (vibration) of the ground and
buildings caused by the earthquake or the like.

25 In view of the above object, it is proposed
according to a general aspect of the invention that when
vibration or shaking due to the earthquake or the like

1 occurs in a particular place where facilities such as an
elevator system or the like whose operation is to be
supervised and installed, a decision as to whether the
supervisory operation should be started is not made in
5 dependence on only the magnitude of vibrational acce-
leration, but the decision is also made in depen-
dence on whether or not a detected product of displace-
ment of the vibration (amplitude value) and speed of the
vibration has attained a predetermined value.

10 The above and other objects, features and
advantages of the invention will be apparent from the
following detailed description taken in conjunction with
the accompanying drawings, in which:

Fig. 1 is a view for graphically showing the
15 relationship between the seismic intensity grade and
acceleration together with the actually measured
results;

Fig. 2 is a view showing schematically a
general arrangement of a system to which the invention
20 is applied;

Fig. 3 is a block diagram showing further
details of a main portion of the system according to an
embodiment of the invention;

Figs. 4, 5 and 6 show flow charts for
25 illustrating examples of the supervised operation of an
elevator system controlled according to the teachings of
the invention;

1 Fig. 7 is a view for graphically illustrating the relation between maximum value of product of speed and displacement of the seismic and the seismic intensity grade together with actually measured values;

5 Fig. 8 is a schematic diagram for illustrating the concept of the invention; and

 Fig. 9 is a block diagram showing a main portion of the system according to another embodiment of the invention.

10 Fig. 2 is a view showing schematically a general arrangement of an equipment to which the invention is applied. The equipment generally denoted by 11 includes a machine room 12 and an object to be controlled which is driven under the command of the
15 supervisory operation control signal issued from the machine room 12. There are disposed within the machine room 12 an acceleration detector 1 for detecting or sensing vibration of the equipment, a control signal generating device 14 for generating a control signal on
20 the basis of the signal produced by the acceleration detector 1, and a supervisory operation control apparatus 15 for performing the supervisory operation of the object 13 to be controlled in accordance with the control signal produced by the control signal generating
25 device 14. The supervisory operation control apparatus of various types have heretofore been proposed and practically used. The invention can be applied to these

1 known supervisory operation control apparatus without
modification. Although the detector 1 is shown as
installed in the machine~~er~~ room, it should be understood
that the detector may be installed at other locations of
5 the equipment than the machine room.

The control signal generating device 14 is
shown in greater detail in Figure 3. The circuit
includes an acceleration detector 1, integrators 2 and
3, a multiplier 4, comparators 5, 6 and 7, an OR gate 8,
10 and an AND gate 9. The integrator 2 integrates the
acceleration signal a which is output from the
acceleration detector 1, in order to produce a speed
signal v. The integrator 3 integrates the speed
signal $\frac{v}{t}$ in order to derive a displacement signal y.
15 The multiplier 4 multiplies the outputs of the two
integrators 2 and 3 so as to obtain on a real time
basis the product v . y of speed and displacement.
The comparators 6 and 7 receive inputs from the output
of the multiplier 4, whilst the comparator 5 receives
20 an input from the output of the acceleration detector
1. The comparators are set to compare the above
referred to outputs with respective comparison levels
previously set. The OR gate 8 receives outputs from
the comparators 5 and 6 and provides a supervisory
25 signal as an output to a terminal Y. The AND gate 9
receives outputs from the OR gate 8 and the comparator
7 and provides a supervisory signal as an output
signal to a terminal R. Accordingly, a supervisory

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signal is output on the terminal Y when the acceleration a or the product v . y of speed and displacement of the seismic wave exceeds a relevant predetermined value. On the other hand, a supervisory signal is output on the terminal R when the supervisory signal output on the terminal Y has been

- 1 produced and when the product $v \cdot y$ of speed and displacement exceeds the value beyond which the machinery of the elevator may fail, involving danger in the elevator operation.
- 5 The following table 5 shows the results of calculation of the product $v \cdot y$ of speed and displacement on the basis of the data contained in the tables 3 and 4. It will be seen that the situation represented by the table 3 corresponds to the seismic intensity
- 10 grade V with the situation listed in the table 4 corresponding to the seismic intensity grade III with very good approximation to the actual situations.

Table 5

	Acceleration in machine room	Intensity corresponding to acceleration	Maximum value of $v \cdot y$ in machine room	Intensity corresponding to maximum $v \cdot y$
Case of table 3	15 Gal	III	$3380 \text{ mm}^2/\text{s}$	V
Case of table 4	30 Gal	II	$100 \text{ mm}^2/\text{s}$	III

- It is now assumed that the comparison level of the comparator 5 shown in Fig. 3 is set at 80 Gal, the
- 15 threshold level of the comparator 6 is set at $1 \times 10^3 \text{ mm}^2/\text{s}$ and that of the comparator 7 is set at 2×10^3

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1 mm^2 / s . On the assumed conditions, no supervisory
signal is generated in the case of the situation listed
in the table 4 although the supervisory signal R is pro-
duced in the case of the earthquake shown in the table 3.
5 In this way, the supervisory operation can be carried
out in a rational manner in dependence on the actual
seismic intensity. The supervisory operation of the
elevator with the aid of these supervisory signals Y and
R is carried out in the same manner as in the case of
10 the hitherto known supervisory elevator operations.
However, for having a better understanding of the inven-
tion, the supervisory operation in which the signals Y
and R are made use of will be described below by
referring to Figs. 4, 5 and 6.

15 Referring to Fig. 4, when the control signal
generating device 14 produces only the signal Y in
response to detection of the vibration of first level
set at the comparators 5 and 6, the elevator car is
stopped at the nearest floor where the door is opened to
20 allow the passengers to get off. Subsequently, the door
is closed and operation of the car is shut down.

 When the vibration of the second level set at
the comparator 7 is also detected, the elevator car is
instantly stopped (emergency stop), as illustrated in
25 Fig. 5. A signal representative of this situation is
transmitted to the supervisor room to inform the super-
visor of the emergency stopping of the car, whereupon the

- 1 supervisor causes the elevator car to run to the nearest
landing floor at a low speed, if the situation allows
it. By opening the door, the passenger can get off the
car. Thereafter, the door is closed and arrival of ser-
5 vice engineers is awaited.

- Fig. 6 illustrates another example of the
supervisory operation according to another embodiment of
the present invention. Referring to the figure, upon
detection only of the vibration of the first level, i.e.
10 upon generation only of the signal Y, the car is caused
to stop at the nearest floor to allow the passengers to
get off by opening the door. The car is subsequently at
rest with the door being closed. When the earthquake is
settled after a time lapse, being accompanied with
15 disappearance of the signal Y, the ordinary car opera-
tion is automatically restored. However, when the
signal R is generated in response to detection of the
vibration of the second level, the elevator car is
instantly stopped as in the case illustrated in Fig. 5.

- 20 Fig. 7 graphically illustrates the relationship
existing between the product $v \cdot y$ (mm^2/S) of the
displacement (amplitude) y (mm) and the speed v (mm/S)
of seismic vibration and the seismic intensity grade
together with the calculated values based on the
25 measured values shown in black spots. As will be
clearly seen in Fig. 7, the product $v \cdot y$ of displace-
ment and speed exhibits very proper correlation with the

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1 seismic intensity grade.

Next, theoretical ground for the existence of the favorable correlation mentioned above will be explained below.

5 Referring to Fig. 8, it is assumed that the seismic wave of wavelength λ and period T reaches at a minute area dS . The phase after lapse of time $T/2$ from the arrival of the seismic wave advances by $\lambda/2$ from the area dS .

10 The seismic waves comprise a longitudinal compressional or primary or P wave and a transverse, shear or secondary or S wave. In terms of energy, it is sufficient to consider only the S wave.

15 Since the S wave is a transverse wave, displacement y brought about by the seismic motion is produced in the direction perpendicular to the propagating direction of the seismic wave.

Time differential of displacement y given by

$$v = \frac{dy}{dt} \dots\dots\dots (1)$$

20 represents the vibrational speed or rate of the seismic motion whose distribution is such as indicated by a broken line in Fig. 8.

Considering a point at which the distance from dS is in the range of 0 to $\lambda/2$, kinetic energy E_v and
25 strain energy E_s per unit volume of medium at that point are, respectively, given by the following expressions.

1 Namely,

$$E_v = \frac{1}{2} \cdot \rho \cdot \left(\frac{dy}{dt}\right)^2 \dots\dots\dots (2)$$

where ρ represents density (g/cm^3) of the medium, and

$$E_s = \frac{1}{2} \cdot \mu \cdot \left(\frac{dy}{dt}\right)^2 \dots\dots\dots (3)$$

5 where μ represents shear modulus of the medium.

When the whole volume $dS \cdot (\lambda/2)$ is considered, the total sum of the kinetic energy is equal to the total sum of the strain energy.

The total sum W_v of kinetic energy is given by

$$\begin{aligned} 10 \quad W_v &= \frac{1}{2} \cdot dS \cdot \frac{\lambda}{2} \cdot \rho \cdot \frac{1}{(T/2)} \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \\ &= \frac{1}{2} \cdot \rho \cdot dS \cdot V_s \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \dots\dots\dots (4) \end{aligned}$$

where V_s represents the propagating speed of the S wave which is given by

$$V_s = \frac{\lambda}{T} \dots\dots\dots (5)$$

15 On the other hand, the total sum W_s of the strain energy is given by

$$\begin{aligned} W_s &= \frac{1}{2} \cdot dS \cdot \frac{\lambda}{2} \cdot \mu \cdot \frac{1}{(T/2)} \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \\ &= \frac{1}{2} \cdot \mu \cdot dS \cdot V_s \cdot \int_0^T \frac{\left(\frac{dy}{dt}\right)^2}{\left(\frac{dx}{dt}\right)^2} dt \end{aligned}$$

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$$\begin{aligned}
 1 \quad &= \frac{1}{2} \cdot \mu \cdot dS \cdot \frac{1}{v_s} \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \\
 &= \frac{1}{2} \cdot \rho \cdot dS \cdot v_s \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \\
 &= W_v \dots\dots\dots (6)
 \end{aligned}$$

In the development of the above expression, the following relation is made use of:

$$v_s = dx/dt = \sqrt{\mu/\rho} \dots\dots\dots (7)$$

Since the whole energy W of the volume dS ($\lambda/2$) is the sum of W_v and W_s ,

$$W = W_v + W_s = \rho \cdot dS \cdot v_s \cdot \int_0^T \left(\frac{dy}{dt}\right)^2 dt \dots (8)$$

10 Now assuming that displacement y of the seismic motion is vibrating in accordance with

$$y = D \cdot \sin 2\pi ft \dots\dots\dots (9)$$

where f represents the frequency (Hz) given by

$$f = 1/T \dots\dots\dots (10)$$

15 then

$$V = dy/dt = 2\pi f \cdot D \cdot \cos 2\pi ft \dots\dots\dots (11)$$

Accordingly, the expression (8) can be rewritten as follows:

1
$$W = \pi^2 \cdot \rho \cdot dS \cdot V_s (D^2/T) = K \cdot dS \cdot (D^2/T)$$

..... (12)

where

$$K = \pi^2 \cdot \rho \cdot V_s = \pi^2 \sqrt{\rho \cdot \mu} \dots\dots\dots (13)$$

5 Since ρ and μ are essentially constant, K may be regarded to be constant.

Accordingly, the wave energy can be determined if the amplitude and period of the vibrational displacement of the point in concern are known, as is pointed
10 out by Takagi in his article cited hereinbefore.

Although the above relation is convenient for determining the wave energy from the oscillogram of the displacement of seismic motion, it is difficult to realize the detector for sensing the wave energy on the
15 realtime basis by making use of the above relation, because the period of the seismic wave is as long as 5 to 10 sec. If the measure against the earthquake is taken by calculating the wave energy after the lapse of the period of such long duration, adequate protection
20 can not be afforded for preventing accidents from occurring because activation of the protecting measures is too late in time. Besides, since the seismic wave is of much complicated waveform, great difficulty will be encountered in determining the period and amplitude
25 (displacement) of the seismic motion. Thus, it becomes

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1 difficult to take the measures most proper to the
seismic motion. Furthermore, the calculator capable of
executing arithmetic operations including division such
as the term D^2/T of the expression (12) is relatively
5 expensive, to another disadvantage.

Such being the circumstances, the inventors
have proceeded with examination as follows.

When the product of the vibrational displace-
ment y and the vibrational speed v of the seismic motion
10 is represented by e_t , the latter can be arithmetically
determined as follows:

$$\begin{aligned} e_t &= y \cdot v \\ &= D \cdot \sin 2\pi ft \cdot 2\pi f D \cdot \cos 2\pi ft \\ &= \pi \cdot f \cdot D^2 \cdot \sin 4\pi ft \\ 15 \quad &= \pi \cdot (D^2/T) \sin 4\pi ft \\ &= e \cdot \sin 4\pi ft \dots\dots\dots (14) \end{aligned}$$

where e represents the amplitude of e_t which is given by

$$e = \pi \cdot (D^2/T) = (\pi/K \cdot dS) W \dots\dots\dots (15)$$

Referring also to the expression (12), it will be seen
20 that the amplitude e of e_t is in proportional relation
to the wave energy. Accordingly, the wave energy can be
determined if e or e_t is known.

The product e_t of the vibrational displacement
 y and the vibrational speed v can be determined with the
25 aid of the circuit arrangement shown in Fig. 3 as the
value changing from time to time on the real-time basis.

- 1 The sensor serving to this end can be implemented in a relatively simplified structure because no dividing operation is included.

5 Since the direction of the seismic wave is not constant, it is necessary to detect the wave energy of the seismic wave in a given direction. The apparatus for detecting the wave energy will be described by referring to Fig. 9.

10 It is now assumed that the seismic wave is propagating in a horizontal plane. Referring to Fig. 9, a pair of acceleration sensors are disposed on the plane in directions y_1 and y_2 , respectively, which are orthogonal to each other, to thereby obtain the amplitudes D_1 and D_2 , respectively, of the vibrational displacement. Then, the wave energy W_1 in the direction y_1 is given by

$$W_1 = K \cdot dS (D_1^2/T) \dots\dots\dots (16)$$

The wave energy in the direction y_2 is given by

$$W_2 = K \cdot dS (D_2^2/T) \dots\dots\dots (17)$$

20. When the sum of W_1 and W_2 is represented by W , then

$$\begin{aligned} W &= W_1 + W_2 \\ &= K \cdot dS \cdot \left(\frac{D_1^2}{T} + \frac{D_2^2}{T} \right) \\ &= K \cdot dS \cdot (D^2/T) \dots\dots\dots (18) \end{aligned}$$

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1 where D is given by

$$D^2 = D_1^2 + D_2^2 \dots\dots\dots (19)$$

and represents the amplitude of the vibrational displacement of the seismic wave propagating along the given
5 direction in the horizontal plane. The wave energy thereof is represented by W.

In Fig. 9, symbols a_1 and a_2 represent the vibrational accelerations in the directions y_1 and y_2 , respectively. Similarly to the case of the embodiment
10 shown in Fig. 3, the vibrational speed V_{y1} and the vibrational displacement y_1 in the direction y_1 are determined and multiplied with each other, the result of which is represented by e_{t1} . Then,

$$\begin{aligned} e_{t1} &= V_{y1} \cdot y_1 \\ &= \pi(D_1^2/T) \sin 4\pi ft \dots\dots\dots (20) \end{aligned}$$

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Similarly, product of the vibrational speed V_{y2} and the vibrational displacement y_2 in the direction y_2 is determined and represented by e_{t2} . Then,

$$\begin{aligned} e_{t2} &= V_{y2} \cdot y_2 \\ &= \pi(D_2^2/T) \sin 4\pi ft \dots\dots\dots (21) \end{aligned}$$

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When the sum of e_{t1} and e_{t2} is represented by e_t ,

$$\begin{aligned}
 e_t &= e_{t1} + e_{t2} \\
 &= \pi \left(\frac{D_1^2}{T} + \frac{D_2^2}{T} \right) \sin 4\pi ft \\
 &= \pi \cdot (D^2/T) \cdot \sin 4\pi ft \\
 &= e \sin 4\pi ft \dots\dots\dots (22)
 \end{aligned}$$

5 where e represents the amplitude of e_t and is given by

$$e = \pi (D^2/T) = (\pi/K \cdot dS) \cdot W \dots\dots\dots (23)$$

It will be seen that the amplitude e of e_t is in proportional relation to the seismic wave energy W in the given direction. This amplitude e is compared with the
 10 preset value through the comparator, as in the case of the embodiment shown in Fig. 3.

As will now be understood from the foregoing theoretical analyses, the product $v \cdot y$ of the speed and displacement of the seismic wave is a quantity which is
 15 in proportion to the seismic wave energy passing the location where the acceleration detector is installed. For this reason, it is believed that the product $v \cdot y$ is in close correlation with the seismic intensity grade, as illustrated in Fig. 7.

20 In the embodiment shown in Fig. 3, the comparator 5 and the logical OR element 8 are employed to generate the supervisory signal Y when the acceleration a exceeds a preset value, e.g. 80 Gal. This arrangement serves for producing instantly the supervisory signal
 25 upon sudden generation of great acceleration as in the

1 case of earthquake whose source lies directly under the
region in concern and additionally serves for backing-up
purpose in case the integrator and the multiplier should
fail.

5 In the foregoing description, the invention is
assumed to be applied to the supervisory operation of
the elevator system. It goes, however, without saying
that the invention is never restricted to the applica-
tion to the elevator system. In the case of other faci-
10 lities than the elevator system, the supervisory signal
derived according to the teachings of the invention can
be utilized for the supervisory operations of such faci-
lities in various manners known per se.

As will now be appreciated, the condition
15 under which the supervisory operation of the elevator
system or the like is put into effect can be made to
conform with the swinging or shaking actually felt
according to the invention. By virtue of this feature,
the supervisory operation can be carried out in a
20 rational manner with an improved reliability upon
generation of vibration or shaking of the building or
the like due to high wind and earthquake without being
subjected to the shortcomings of the prior art tech-
niques, whereby the supervisory operation control system
25 which can assure well balanced high security with the
practical applications is realized.



CLAIMS

1. A supervisory operation control system including vibration detecting means for detecting vibration occurring at a predetermined location of an equipment, control signal generating means for generating a control signal when a value relating to said vibration and derived from the detection signal produced by said detecting means exceeds at least one predetermined value and supervisory operation controlling means for controlling the supervisory operation of said equipment in dependence on said control signal produced by said control signal generating means, wherein said control signal generating means comprises:

(a) speed/displacement detecting means for determining the speed and displacement of said vibration on the basis of said detection signal;

(b) multiplying means for determining a product of said speed and displacement obtained through said speed/displacement detecting means; and

(c) comparing means for generating the control signal when the value of said product determined by said multiplying means exceeds said predetermined value.

2. A supervisory operation control system according to claim 1, wherein said vibration detecting means is constituted by an acceleration detector.

3. A supervisory operation control system according to claim 2, wherein said speed/displacement



detecting means is composed of a first integrating stage for determining the speed by integrating the detection signal produced by said acceleration detector and a second integrating stage for integrating the speed determined by said first integrating stage to thereby determine the displacement.

4. A supervisory operation control system according to claim 2, wherein said comparing means further includes comparison means for generating the control signal when the detection signal outputted from said acceleration detector exceeds the predetermined value.

5. A supervisory operation control system according to claim 1, wherein said comparing means includes first comparison means for generating a first control signal when the value of said product exceeds a first predetermined value, and a second comparison means for generating a second control signal when the value of said product exceeds a second predetermined value which is greater than said first predetermined value, said supervisory operation control means performing operations which differ from each other in dependence on whether only said first control signal is received or said second control signal is received.

6. A supervisory operation control system according to claim 1, wherein said vibration detecting means is composed of at least two vibration detectors



for detecting vibrations of mutually different directions.

7. A supervisory operation control system according to claim 6, wherein said control signal generating means includes speed/displacement detecting means for determining said speed and displacement on the basis of the detection signals produced by said vibration detectors and multiplying means for determining a product of said speed and displacement, and adding means for adding values of said products.

8. A supervisory operation control system according to claim 7, wherein said comparing means compares the added values produced from said adding means with said predetermined value.

9. A supervisory operation control system constructed substantially as herein described with reference to and as illustrated in Figs. 2 to 9 of the accompanying drawings.
