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(54) **Apparatus and process for controlling the shape of sheet metal produced in a rolling mill.**

(57) The invention relates to an apparatus and process for automatically controlling the shape of sheet metal (10) produced in a rolling mill. The shape of the sheet (10) is sensed by a shapemeter (9) and each segment of the shapemeter provides an output indicative of the shape of the portion of the sheet passing over that segment. A converter (15) converts the outputs to electrical signal levels, such as current or voltage levels, and certain ones of the signal levels are averaged, and the averages are compared either with certain other signals levels, or with certain other averages in a processor (17). If the comparisons yield a difference greater than predetermined tolerance levels, control signals are generated and delivered to output controllers (19) to control parameters of the rolling mill.

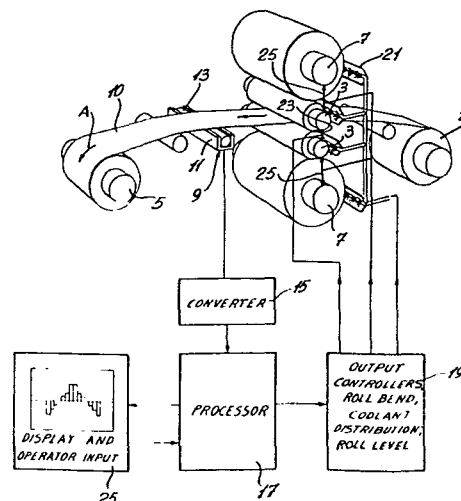


Fig. 1

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DESCRIPTION"APPARATUS AND PROCESS FOR CONTROLLING
THE SHAPE OF SHEET METAL PRODUCED IN
A ROLLING MILL"

The invention relates to an apparatus and a process for controlling the shape of sheet metal produced in a rolling mill. Apparatuses are known which are arranged so as, in use, to receive a
5 plurality of output signals from a sensor disposed across the width of said metal sheet, said sensor having a plurality of individual sensing means disposed at different locations across said width, a different one of said plurality of signals being
10 associated with a different one of said individual sensing means.

As is known in this art, shape is defined as the cross sectional profile of a strip width of sheet metal with reference to a flat plane. A
15 shapemeter is a device for measuring shape, and examples of such shapemeters are described in British Patent 1,160,112 as well as the brochure of Davy-Loewy Limited, Loewy Robertson Division, entitled "Vidimon Shapemeter". The shapemeter is capable
20 of detecting and displaying the degree and location of any out of flatness condition of a strip under tension which may, visually, appear to be flat.

At present, the display of the shapemeter is monitored by a mill operator who applies appropriate
25 control signals to correct the out of flat conditions. As will be appreciated, the operator can only initiate corrective action after the out of flat condition

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has existed for some time. Further, the reflex and speed limitations of human beings prevents corrective action from being immediately taken so that the out of flat condition will persist for some time after it is detected and displayed.

5 Teachings in the art which relate to controlling the shape of metal sheets produced in a rolling mill are exemplified by the following United States Patents: 2,696,698; 3,064,509; 3,630,055; 10 3,686,907; 3,875,776; 3,882,709; 3,332,263; 3,514,984; 3,431,761; 3,475,935; 2,961,901; 3,213,665; 3,499,306 and 3,802,237.

Although it has been suggested that the output of the shapemeter be fed to a system for automatically initiating corrective action, applicant is 15 not presently aware of the existence of a physical system for so doing.

It is therefore an object of the invention to provide an apparatus and process for automatically 20 controlling the shape of aluminum sheet produced in a rolling mill.

Apparatus according to the invention is characterised in that the apparatus comprises: averaging means arranged to receive predetermined ones 25 of said plurality of signals whereby the average of said predetermined ones of said plurality of signals is produced at an output of said averaging means; comparator means arranged to receive at one input terminal thereof the output of said averaging means 30 and to receive at a second input terminal, predetermined other ones of said plurality of signals or other averages thereof; and control means arranged to receive the output of said comparator means for controlling a parameter of said rolling mill whereby,

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when said comparator means detects greater than a predetermined difference between the inputs thereof, said parameter will be appropriately controlled.

5 Other optional features of the apparatus are defined in the subsidiary claims appended hereto.

The process according to the invention is characterised in that the process comprises: forming a signal representative of the average of predetermined ones of said signals, comprising said signal with
10 a further signal representative of predetermined other ones of said signal or of other averages thereof and when the difference between the compared signals exceeds a predetermined amount, controlling a parameter of the rolling mill in a manner to reduce said difference.

15 The invention will be further described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of one embodiment of apparatus in
20 accordance with the present invention and arranged to carry out the process of the invention;
Figure 2 shows part of the Figure 1 in greater detail;
25 Figure 3 shows one form of analog averaging circuit; and
Figure 4 shows one form of digital averaging circuit.

Referring to figure 1, the rolling mill process
30 is somewhat schematically represented by a roll of sheet metal 1, such as aluminum, drawn in the direction of the arrow A through shaping rolls 3 by driven roll 5. Back up rolls 7 are also provided as well known in the art, and a shapemeter 9, for example, of the type described

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in British Patent 1,160,112, the teachings of which are incorporated herein by reference, disposed across the width of the sheet 10, senses the shape of the sheet after it has passed through the shaping rolls.

5 As described in the above mentioned British Patent, the shape meter consists of a stationary arbor 11 and a segmented rotor 13 supported in the arbor by an air cushion and rotatable therein. This assembly produces pneumatic signals which, in the present
10 application, are converted to electrical signals by converter 15, as well known in the art, as the apparatus in accordance with the invention comprises electronic circuitry.

15 The pneumatic signals are a function of the strip force applied to each rotor segment, and the pneumatic signals are converted to electrical levels, such as voltage levels or current levels, proportional to the level of the pneumatic signals.

20 The output of 15 is fed to processor 17, which could consist of discrete circuits as described below, or which could comprise a micro-processor with an appropriately programmed RAM.

25 The processor produces control signals fed to means for controlling the roll bend, means for controlling coolant distribution, and means for leveling the rolls. Although such means are illustrated in a single block 19 in figure 1, it will be appreciated that they are, in practice, separate means which are part of existing rolling mill systems.

30 The coolant distribution means comprise a series of sprays, schematically shown at 21 in figure 1, disposed across the width of the sheet 10. The means for controlling the roll bend are schematically illustrated by the arrows 23, and the means for leveling the rolls

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are schematically illustrated by the arrows 25. As above mentioned, these means are well known in the art, and it is therefore not necessary to describe them any further here.

5 The output of the processor is also applied to display means 25, which is preferably a CRT, as some of the control functions may be manually controlled rather than automatically. Thus, it is within the scope of the invention to provide an apparatus by which only roll
10 bending and coolant distribution are automatically controlled, while roll leveling is operator controlled.

 In accordance with the invention, certain ones of the signals from 9 are averaged, and the average thus obtained is compared with certain other ones of the
15 signals or with averages of certain other ones of the signals, the result of the comparison constituting the control signals. The ones of the signals and the other ones of the signals could overlap, and, indeed, the ones and the other ones could constitute identical sets of
20 signals. However, the average would be formed by all of the ones of the signals at the same time, and the average would then be compared to the other ones of the signals one at a time, as will be described below.

 Turning now to figure 2, there is illustrated,
25 in block diagram form, an arrangement which could perform the functions of the block 17 of figure 1. In figure 2, the designations AL_1 to AL_7 represent the signals from the rotors on the left hand side of the sheet, and the designations AR_1 to AR_7 represent the
30 signals from the rotors on the right hand side of the sheet and the designation AC represents the signal from the central rotor, in a 15 segment shapemeter. These signals are fed to the averaging circuits which will provide averages as required and as described below.

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Figures 3 and 4 illustrate, respectively, an analog and a digital circuit for averaging. In figure 3, the ratio $R_1/R_1+R_6=1/7$, when there are 7 inputs being averaged. The circuits of figures 3 and 4 are exemplary only, and the operation thereof is straight forward so that no further description thereof is required.

In considering now the process of operating the apparatus as is known, it is desired to produce a sheet whose thickness is consistent throughout within stated tolerance limitations. However, portions having thicknesses above or below tolerance limitations will develop, and these portions will produce, respectively, greater or lesser pressures on their adjacent rotors and thereby be detected.

In order to increase or decrease the thickness of the sheet in such a portion, the output of its adjacent spray is either increased or decreased. Thus, coolant distribution is one parameter and controlling the coolant distribution is one function of the process and apparatus.

In accordance with the invention, in order to correct such deviations in thickness, the outputs of all rotors are averaged, and the output of each rotor is then compared to this average one at a time.

Referring to figure 2, the signal AV_T represents the average of all signals AL_1 to AL_7 , AC and AR_1 to AR_7 . AV_T is applied at one input terminal of each of comparators CL_1 to CL_7 , CC and CR_1 to CR_7 . The other input terminal to these comparators is fed, respectively, AL_1 to AL_7 , AC and AR_1 to AR_7 . If the output of any of the comparators is greater, in the positive or negative directions, from a preset tolerance limit, then the spray adjacent the rotor from which the other input terminal to the respective comparator is fed is

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appropriately controlled to either increase or decrease its output. The spray will continue at this changed level until the output of the respective comparator falls within the tolerance limits, whereupon it will resume its normal level.

To determine whether it is necessary to level the shaping rolls, two averages are required - the average of all signals from the rotors on the left hand side of the sheet, AV_L - and the average of all signals from the rotors on the right hand side of the sheet AV_R . If the average on the right hand side is greater than the average on the left hand side, this means that more pressure is being exerted on the right hand rotors than on the left hand rotors, i.e., the right hand side of the roll is closer to the sheet than the left hand side of the roll. The roll must thus be releveled to tilt the right hand side upward (away from the sheet), and the left hand side downward (towards the roll). AV_L and AV_R are compared in comparator LC, and if the output of this comparator exceeds tolerance limits, the leveling mechanism is actuated to relevel the roll. As above mentioned, the function controlling this second parameter can be performed automatically, or it can be operator controlled.

The cross-sectional shape of the sheet, or mill roll flexure, is a function of the material being shaped as well as the requirements of the particular mill, and this parameter must also be monitored. To perform this monitoring function, an average is taken of signals from a proportion of the outside segments on the right hand side of the sheet - AVO_R , a second average is taken of signals from a proportion of the outside segments on the left hand side of the sheet - AVO_L , and a third average is taken from a proportion of segments at the center

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of the sheet - AV_C . In one embodiment, the proportions are 25%, 25% and 50%. Thus, in the illustrated embodiment, AV_L is formed from signals AL_1 to AL_4 , AV_R is formed from signals AR_1 to AR_4 , and AV_C is formed from signals A_C , AL_1 , AL_2 , AR_1 and AR_2 .

The averages so formed are fed to the processor PR in figure 2 which has, stored in its memory, the required averages for the desired shape. Any deviations beyond tolerance from the required averages will provide a control signal to the roll bending mechanism to bend the roll so as to produce a sheet of the required shape.

With automatic detection and control, detection of deviations and controls to correct them are almost instantaneous. Regardless of the experience of an operator, his speed of response can never even approximate the speed of electronic response, so that shape of the sheet will be improved due to automatic control. However, the human element can never be fully programmed into a machine, so that overrides should be provided to allow the operator to include the human element and experience in the process.

In the above description, we have assumed a shapemeter having fifteen rotors. As is known, the same mill may be used to shape wider or narrower sheets. To accommodate all widths of sheets, the sheet is centered on the sensor, and any unused rotors on both ends thereof are turned off, as well known in the art. Of course, shapemeters with different numbers of rotors can also be used.

Although several embodiments have been described, this was for the purpose of illustrating, but not limiting, the invention. Various modifications, which will come readily to the mind of one skilled in the art, are within the scope of the invention as defined in the appended claims.

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C L A I M S

1. Apparatus for controlling the shape of sheet metal produced in a rolling mill, said apparatus being arranged so as, in use, to receive a plurality of output signals from a sensor disposed across the width of said metal sheet, said sensor having a plurality of individual sensing means disposed at different locations across said width, a different one of said plurality of signals being associated with a different one of said individual sensing means characterised in that the apparatus comprises: averaging means arranged to receive predetermined ones of said plurality of signals whereby the average of said predetermined ones of said plurality of signals is produced at an output of said averaging means; comparator means arranged to receive at one input terminal thereof the output of said averaging means and to receive at a second input terminal, predetermined other ones of said plurality of signals or other averages thereof; and control means arranged to receive the output of said comparator means for controlling a parameter of said rolling mill whereby, when said comparator means detects greater than a predetermined difference between the inputs thereof, said parameter will be appropriately controlled.

2. Apparatus as defined in claim 1 characterised in that said sensor comprises a shapemeter having a plurality of segments, a different one of said segments of said shapemeter being associated with a different one of said plurality of signals and in that

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said plurality of signals comprise electrical signal levels, said averaging means comprise electronic averaging means; and said comparator means comprise electronic comparator means.

3. Apparatus as defined in claim 2 characterised in that said predetermined ones of said plurality of signals comprise all of said plurality of signals, whereby the output of said averaging means is the average of all of said plurality of signals, said comparator means comprises a plurality of comparators equal in number to the plurality of signals, the output of said averaging means is fed to one input terminal of each of said plurality of comparators, a different one of said plurality of signals is fed to a second input terminal of a respective one of said plurality of comparators, and the output of each comparator is fed to a spray control means, each spray control means being associated with a separate spray means and each spray means being disposed in a position across the width of said roll corresponding, respectively, with the position of the segment which provides the signal feed to its respective comparator whereby, when a signal has a difference from the average equal to or greater than a predetermined amount, the spray associated with the segment from which the signal is provided will be controlled to operate in a manner to reduce said difference.

4. Apparatus as defined in claim 2 characterised in that said averaging means comprises two averagers, the signals from the segments on the right hand side of the sheet being fed to one of said averagers and the signals from the segments on the left hand side of the sheet being fed to the other of the averagers;

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the output of said one averager being fed to one input terminal of said comparator means; and the output of said comparator means being fed to a roll level controller whereby when the difference in value between the inputs to the comparator means equals or exceeds a predetermined amount, the level controller will control the roll level means to operate to eliminate the difference.

5. Apparatus as defined in claim 2 characterised in that said averaging means comprises first, second and third averagers and said comparator means comprises a processor, a first portion of said plurality of signals, derived from a first portion of segments on the outer right hand side of said sheet being fed to said first averager, a second portion of said plurality of signals, derived from a second portion of segments on the outer left hand side of said sheet being fed to said second averager; a third portion of said plurality of signals, derived from the central segments, being fed to said third averager and the outputs of said averagers being fed to respective input terminals of said processor which has, stored in memory, required respective averages whereby, when the outputs of said averagers differ from said required averages by an amount equal to or greater than a predetermined amount, the roll bend means are controlled to bend the roll back to reduce the differences.

6. Apparatus as defined in claim 5 characterised in that said first portion of segments comprises the 25% of the segments disposed on the outer right hand side of said sheet, said second portion of segments comprises the 25% of the segments disposed on the outer left hand side of said sheet and wherein said third portion comprises the 50% of the segments disposed centrally of said sheet.

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7. A process for controlling the shape of sheet metal produced in a rolling mill, the method comprising obtaining a plurality of output signals from a sensor disposed across the width of said metal sheet, said sensor having a plurality of individual sensing means disposed at different locations across said width, a different one of said plurality of signals being associated with a different one of said individual sensing means characterised in that the process comprises: forming a signal representative of the average of predetermined ones of said signals, comparing said signal with a further signal representative of predetermined other ones of said signal or of other averages thereof and when the difference between the compared signals exceeds a predetermined amount, controlling a parameter of the rolling mill in a manner to reduce said difference.

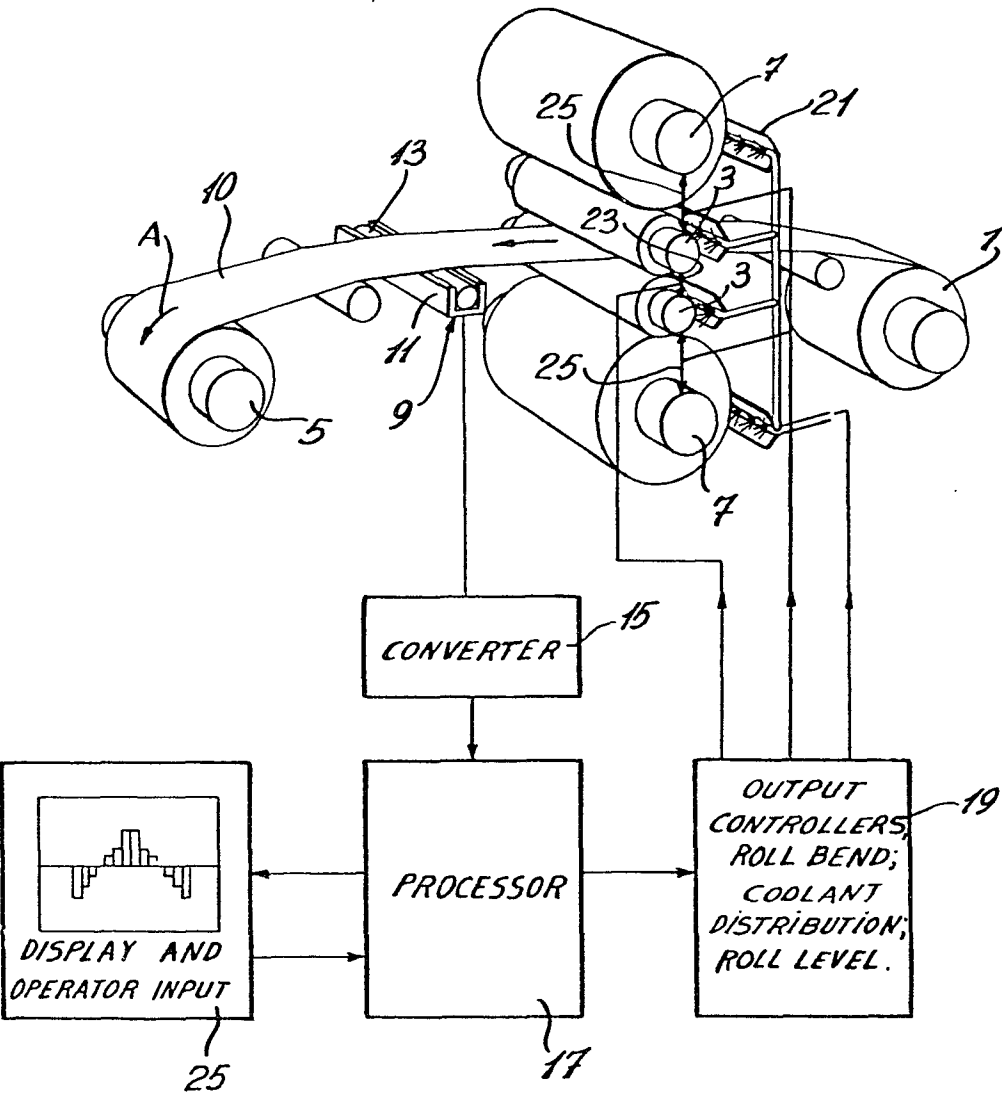
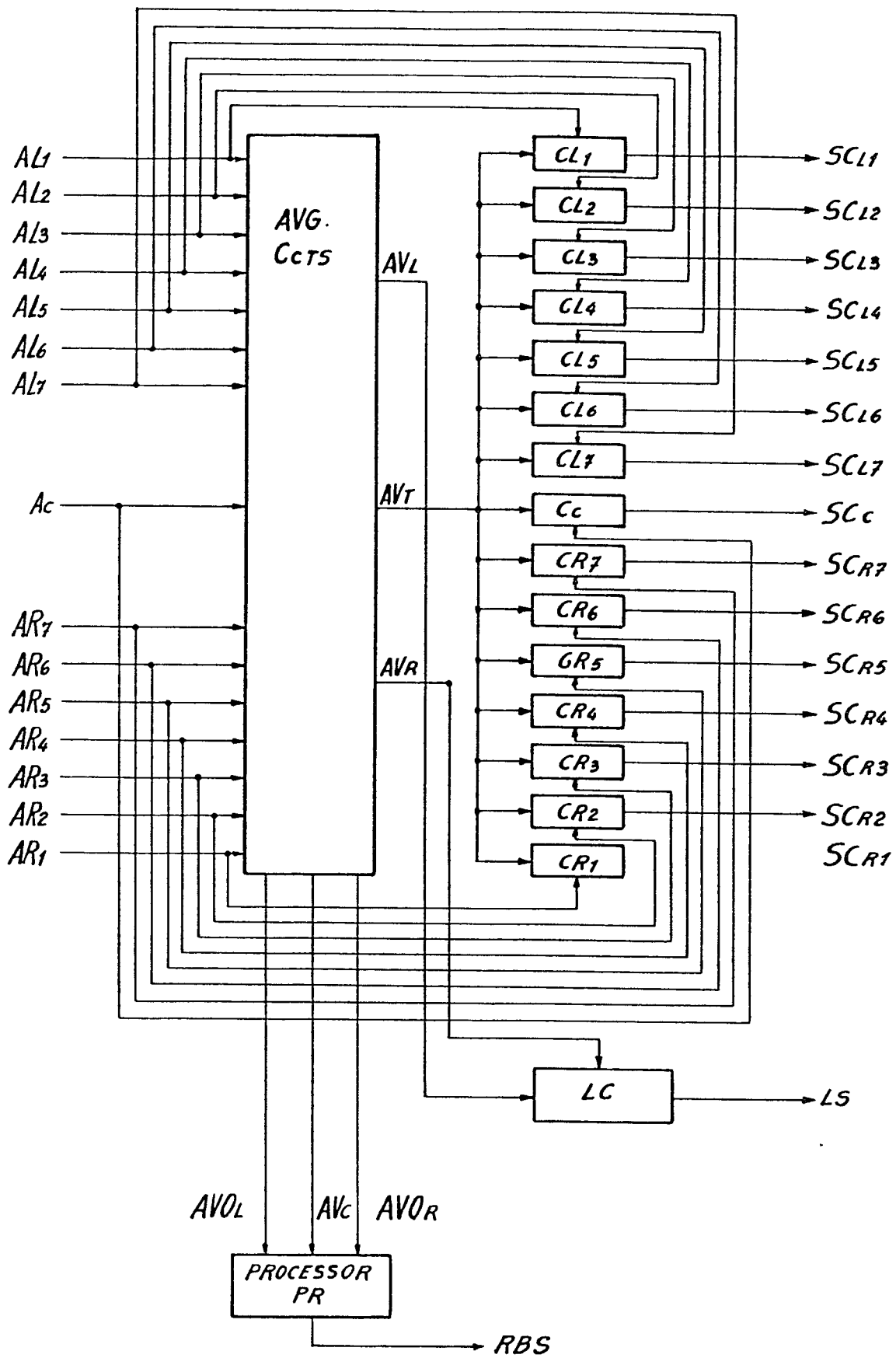
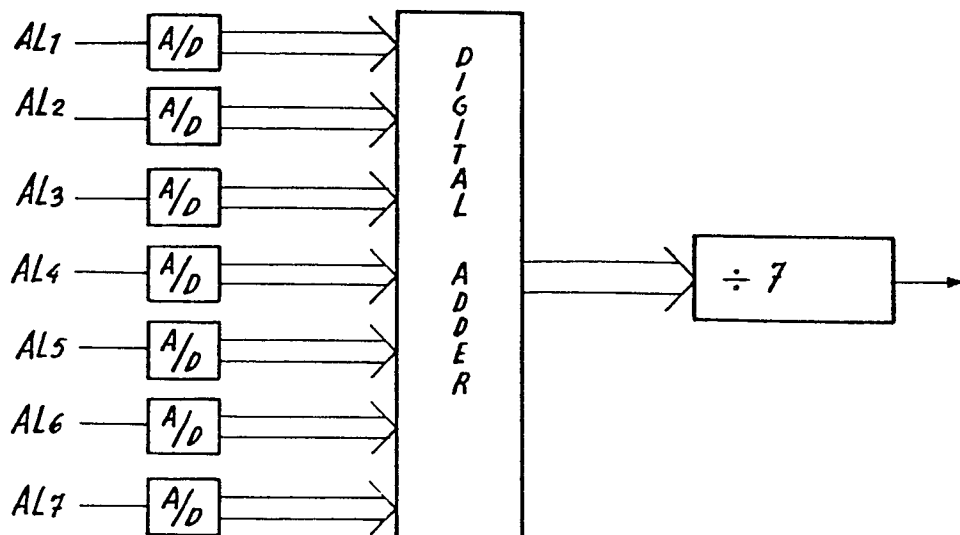
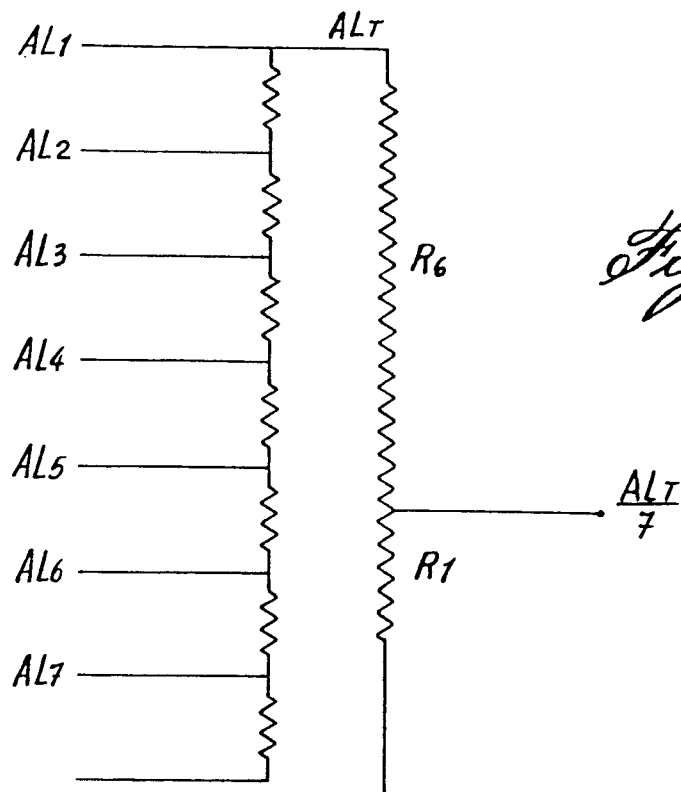


Fig. 1

*Fig. 2*

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European Patent
Office

EUROPEAN SEARCH REPORT

0028275

Application number

EP 79 30 2409.2

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	DE - A1 - 2 555 677 (ESCHER WYSS) * claims 1 to 7; page 10 * --	1,2	B 21 B 37/08 G 05 D 5/03
X	DE - A1 - 2 554 246 (ACHENBACH BUSCHHÜTTEN) * claims 1 to 7; fig. 1 * --	1-3	
D	US - A - 3 431 761 (CLEMENT) * complete document * --		TECHNICAL FIELDS SEARCHED (Int. Cl.3)
D	US - A - 3 630 055 (FAPIANO et al.) * complete document * --		B 21 B 13/00 B 21 B 37/00 G 05 D 5/03
D	US - A - 3 882 709 (KAWAMOTO et al.) * complete document * --		
	DE - A1 - 2 349 611 (ACHENBACH BUSCHHÜTTEN) * claims 1 to 3 * --	1	CATEGORY OF CITED DOCUMENTS
	DE - A1 - 2 532 743 (NIPPON KOKAN) * claims 1, 6; fig. 10 * --	1,2	X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
	US - A - 3 756 050 (KUBO et al.) * claims 1 to 5 * --	1	
X The present search report has been drawn up for all claims			&: member of the same patent family, corresponding document
Place of search Berlin		Date of completion of the search 30-06-1980	Examiner SCHLAITZ



DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	<u>US - A - 3 526 114 (WISTREICH)</u> * claims 1 to 5; column 5 * -- <u>US - A - 3 648 496 (PETRY et al.)</u> * column 3 * -- <u>US - A - 3 315 506 (SCHNEIDER)</u> * claims 1, 2 * -- <u>GB - A - 982 231 (WESTINGHOUSE)</u> * claims 1 to 3; fig. 10 * -- A <u>DE - A - 2 156 707 (KOBE STEEL)</u> * complete document * -- A <u>GB - A - 1 177 508 (DAVY AND UNITED INSTRUMENTS)</u> * complete document * -- A <u>US - A - 3 587 265 (SIVILOTTI)</u> * complete document * -----	1,2 1 1 1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.3)