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AUTOMATIC POSITIONING SYSTEM HAVING TAPE RESPONSIVE SERVO MEANS

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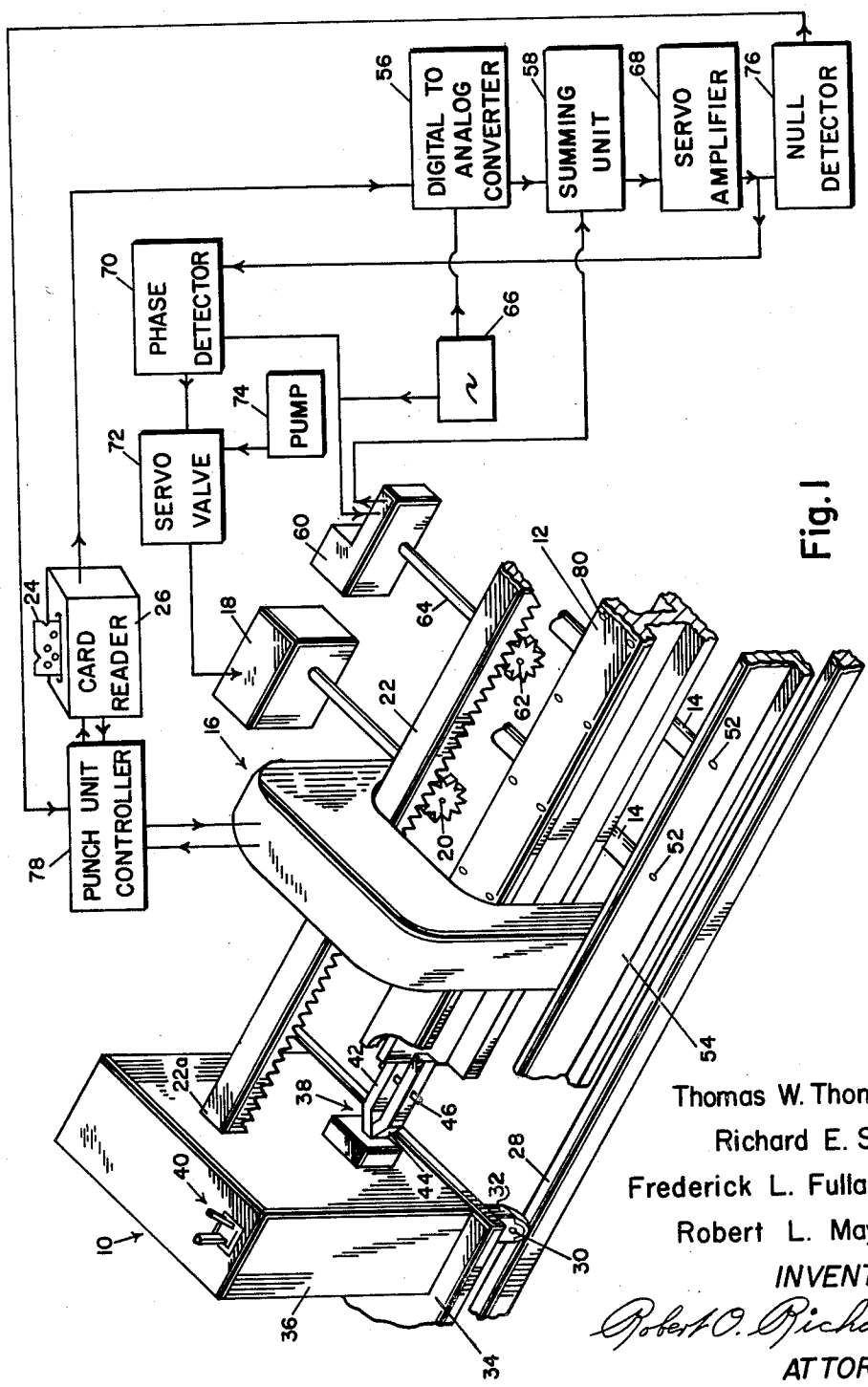


Fig. 1

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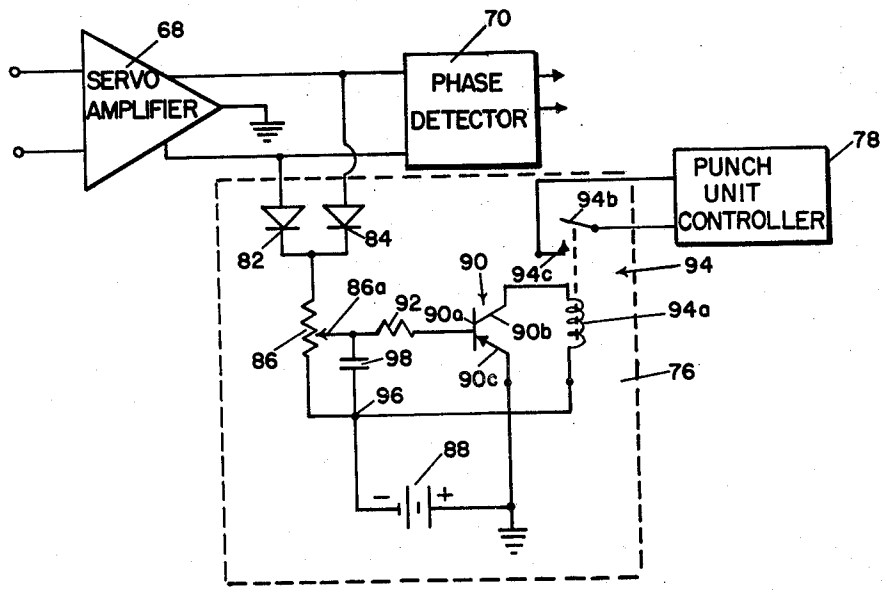


Fig. 2

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AUTOMATIC POSITIONING SYSTEM HAVING TAPE RESPONSIVE SERVO MEANS

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9 Claims. (Cl. 83—71)

This invention relates to an improved automatic positioning system. More particularly, it relates to a control system which positions successive points of a long steel beam under a punch press for accurate punching of the beam according to digitally recorded instructions.

In most structures using steel beams, there is a requirement that the beams have holes at various positions along their lengths for connection to other structural members by means of rivets or bolts. The holes are most readily formed by means of punch presses, which are located at the installations where the beams are cut to size and trimmed and otherwise prepared for erection at the construction site. The weight of a steel beam of even moderate length is sufficient to make machine-aided positioning of the beam with respect to the punch press very desirable. In turn, the use of such machinery militates toward automatic control thereof to obtain the various punch locations. Another important factor is the time and difficulty involved in making hand measurements on beams of moderate or greater length.

Accordingly, it is a principal object of our invention to provide an automatic machine tool capable of performing operations at successive points along an elongated work piece of considerable length.

A more specific object of the invention is to provide apparatus for automatically punching holes in steel beams at various predetermined positions therealong.

A further object of the invention is to provide apparatus of the above type which accurately locates the holes to be punched.

Yet another object is to provide apparatus of the above type which is well adapted to punch holes at different locations on successive beams.

A still further object of the invention is to provide a machine tool of the above type which is relatively simple in design yet reliable and accurate in operation.

Other objects of our invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of element, and arrangement of parts which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

In general, our invention uses a servo controlled hydraulic motor to position beams in the proper location beneath a punch press. The electric-hydraulic servosystem operates in response to signals developed from instructions programmed in digital form on data storage devices such as punched cards. The use of such cards facilitates variation of the punching instructions for different beam.

The beam to be punched rides on rollers which support its weight and minimize frictional forces during movement. It is pulled or pushed over the rollers, as the case may be, by a carriage supported on rails and driven therealong by the servomotor. The servomotor operates through a pinion meshing with a rack affixed to the carriage. A feedback transducer provides a signal indicative of the position of the carriage and the beam attached thereto, by means of a second pinion connected to the rack and rotated in accordance with its movement. The

output of the transducer is used to provide a conventional error signal for the servosystem.

The system is relatively simple in design and yet it positions the beams with a high degree of accuracy. Furthermore, its simplicity, together with the inherent ruggedness of the positioning mechanism, provides a high degree of reliability. Reliability is enhanced by a novel null detector which determines when the beam has finally come to rest in the correct location and emits a signal initiating the punching operation. Another advantage of our system is the fact that it is readily used with existing beam-punching equipment.

For a fuller understanding of the nature and objects of invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a schematic representation of a beam punching system incorporating the principles of our invention and includes a simplified perspective view of the punch press and associated mechanical elements, and

FIGURE 2 is a schematic diagram of the null detector used to initiate the punching cycle.

As seen in FIGURE 1, a carriage generally indicated at **10** moves a beam **12** over rollers **14** to position the beam beneath a stationary punch unit generally indicated at **16**. The carriage **10** is powered by a hydraulic servo motor **18** acting through a pinion **20** which meshes with a rack **22** attached to the carriage. The motor **18** is controlled by a servosystem in accordance with instructions recorded on punched cards **24** fed to a card reader **26**.

More specifically, the carriage **10** rides over a pair of rails **28** by means of wheels **30** journalled in columns **32**. The columns **32** support a base plate **34** to which is secured a housing **36**. The housing **36** contains a power unit which operates a gripper, generally indicated at **38** in accordance with the setting of gripper controls generally indicated at **40**. The gripper **38** includes arms **42** and **44**, which engage the beam **12**, and a reference pin **46** extending through and in slidable engagement with the arms **42** and **44**. The end of the beam **12** within the gripper **38** bottoms against the pin **46**, thereby providing a fixed correspondence of points along the beam with points along the rack **22**. Still referring to FIGURE 1, an end **22***a* of the rack **22** is suitably secured to the housing **36** and the rack is supported by a roller support not shown.

The output of the card reader **26** is converted to an analog signal by a digital-to-analog converter **56**. The output of the converter **56** is one of the inputs of a summing unit **58**. The other input of the summing unit is taken from a position sensor, generally indicated at **60**, coupled to the rack **22** by a pinion **62** keyed to a shaft **64**. The sensor **60** may be a conventional device providing an electrical output signal indicative of the number of pinion turns and fractions there of from a zero or reference angle. Thus, the transducer output signal corresponds to the position of the rack **22**, which rotates the pinion **62** as it moves together with the beam **12**.

Preferably, sensor **60** is of the autotransformer type in which a plurality of taps on an autotransformer are selectively switched, as the pinion **62** rotates, to vary in discrete steps the output voltage of the transformer. A potentiometer may also be included for interpolation between the voltage increments. The converter **56** may be a similar unit, with connections to the taps of autotransformers made by relays actuated in accordance with holes in the punched card **24**. Preferably, the converter **56** and sensor **60** are both excited by an alternating current power source **66**. Therefore, the ratio of the output voltages of the converter and transducer is independent of the output voltage of the source **66** and, more important, when the actual position of the beam **12**, as indicated by the voltage from the sensor **60**, is equal to the desired positions as

indicated by the output of the converter 56, the two voltages will be equal regardless of variations in power supply voltage.

The summing unit 58 subtracts one of its input voltages from the other, and, therefore, its output voltage, as applied to an amplifier 68, is an error signal corresponding to the difference between the desired and actual positions of the beam 12. The output of the servoamplifier 68 serves as one input for a phase detector 70, whose other input is a reference voltage from the power source 66. Thus, the detector 70 has a direct-current output whose magnitude is proportional to the positional error of the beam 12 and whose polarity indicates the direction of the error. This signal is used to operate a servo valve 72 controlling the fluid flow from a hydraulic pump 74 to the hydraulic motor 18. The direction of fluid flow to the motor 18 is controlled by the servo valve 72 such as to reduce the positional error of the beam 12 and thus to move it to the desired position recorded on the card 24.

The output of the amplifier 68 is also applied to a null detector 76, to be described in detail, which emits a signal to a punch unit controller 78 when the beam 12 has come to rest in the desired position. In accordance with the instructions on the card 24, the controller 78 determines which of several punches (not shown) in the unit 16, arranged across the beam 12, are to be operated at the various punch locations reached by means of the above positioning system. Thus, various combinations of holes at the different locations may be obtained, as shown by the holes 80 of FIGURE 1. Each punching operation is initiated by the signal from the null detector 76. Preferably, the punch unit 16 also includes means (not shown) for sensing completion of the punching operation and transmitting a signal to the controller 78, which retracts the punches and, in turn, emits a signal to the card reader 26. The card reader thereupon advances the card 24 to read the next set of punching instructions, i.e., the longitudinal and transverse location of the next set of holes 80 in the beam 12.

In many servo positioning systems, an indication that a desired position has been finally reached may be taken directly from the output of the servo amplifier, since the output registers a null when the position error is zero. However, we have found that in the system described above, greatly improved results are obtained by using the null detector 76, shown schematically in FIGURE 2. The detector includes a full wave rectifier comprising diodes 82 and 84 connected to rectify the output of the amplifier 68. The diodes are connected to one end of a potentiometer 86, the other end of which is returned to ground through a battery 88, whose polarity is opposite to that of the rectifier. The movable tap 86*a* of the potentiometer 86 is connected to the base 90*a* of a p-n-p transistor 90 by way of current limiting resistor 92. The coil 94*a* of a relay generally indicated at 94 is connected between the collector 90*b* of the transistor 90 and the junction of the potentiometer 86 and battery 88. The emitter 90*c* of the transistor is connected to the other terminal of the battery, i.e., ground. The relay 94 also includes normally open contacts 94*b* and 94*c*, which are closed when the coil 94*a* is energized, to complete a circuit in the controller 78 and thereby initiate the punching operation. A capacitor 98 is connected between the tap 86*a* and the junction 96.

Still referring to FIGURE 2, whenever there is an error in the position of the beam 12 (FIGURE 1), i.e., when the beam is being moved to a new punch location, a positive voltage appears at the output of the full wave rectifier diodes 82 and 84. Assuming the proper setting of the tap 86*a*, as set forth below, the tap will also be at a positive potential, and, with this potential applied to the base 90*a*, the transistor 90 will be cut off and relay coil 94*a* is not energized. When the beam 12 comes to rest in a punch location, the voltage from the rectifier drops, and the tap 86*a* moves to a negative potential. This causes base-emitter conduction in the transistor 90, with resulting emitter-collector conduction through the relay coil 94*a*. The relay contacts 94*b*, 94*c* are closed by the energized coil to initiate the punching operation.

As is always the case in automatic positioning systems, the system described above generally does not bring the beam to rest in exactly the desired location. Thus, when the beam comes to rest, there is generally a small error signal which is insufficient to cause operation of the hydraulic motor 18, but which does appear at the output of the rectifier contained in the detector 76. Thus, if the tap 86*a* were positioned at the top of the potentiometer 86, its potential and that of the transistor base 90*a* would almost always remain positive, even with the beam 12 in position for the punching operation, and, therefore, the latter operation would not be initiated by the null detector. Accordingly, the tap 86*a* is positioned down on the potentiometer a sufficient distance to obtain a negative voltage whenever the error signal obtained with the beam 12 at rest drops below the level corresponding to the maximum final positional error to be expected.

The capacitor 98 serves two functions. It insures stoppage of the beam 12 in the desired location before the punching operation begins and it also prevents damage to the punch unit 16 in case of failure of the power supply 88 or the amplifier 68. The beams punched by the system may vary widely in weight, and, therefore, the response time of the servosystem may differ considerably from beam to beam. As a result, some beams may overshoot their final position, i.e., pass through from one direction and then return from the other direction. In other cases, the beams may coast from the position corresponding to the setting of the potentiometer tap 86*a* to a position corresponding to a considerably smaller error voltage. In either of these cases, if the detector 76 emits a signal when the error voltage first drops below the level corresponding to the potentiometer setting, the punch unit 16 will be actuated before the beam 12 comes to rest, with resulting damage to the punch unit.

As the beam 12 moves to a new punch location, the amplified error signal diminishes continuously until the desired position of the beam is reached. The voltage across the capacitor 98 moves toward a valve level corresponding to the error voltage. More particularly, it tends toward the difference between the voltage of the battery 88 and the rectified error voltage, multiplied by the ratio of the resistance between the tap 86*a* and the junction 96 to the entire resistance of the potentiometer 86. Because of the time constant involved in charging the capacitor, its voltage lags behind the level corresponding to the error voltage. In particular, as the beam approaches its final position, the capacitor voltage is somewhat greater than the corresponding level, although both are, of course, decreasing.

Thus, when the error voltage drops to a point at which the corresponding voltage level is such as to permit conduction in the transistor 90 to initiate operation of the punch unit, the actual voltage at the tap 86*a* is greater than this valve. Conduction in the transistor is therefore delayed for a length of time determined by the time constant of the capacitor 98 and associated discharge paths through the potentiometer 86. The position of the tap 86*a* along the potentiometer 86 determines both the value of the error signal providing a corresponding level at the tap resulting in transistor conduction and the time constant of the capacitor discharge determining the delay between the time this level is attained and conduction actually begins. The tap 86*a* is set so that transistor conduction will not start until the beam comes to rest.

In other words, when the error signal drops below the valve required to provide a power output from the motor 18 (FIGURE 1) and the beam 12 moves toward its final position, the holding action of the capacitor 98 prevents conduction in the transistor 90, thus delaying punch unit operation until the beam is actually at rest. In

cases where there is overshoot, the error signal rises above the valve corresponding to transistor **90** conduction and thus prevents further discharge of the capacitor **98**. Then, as the beam **12** reverses direction and returns toward its rest position, the capacitor again discharges to provide delayed transistor conduction in the manner described.

Should the servo amplifier **68** fail, the power to the motor **18** will be cut off and the beam **12** will come to a stop. At the same time, the rectified error signal applied to the potentiometer **86** will drop to initiate the punch operation although the beam is not in the correct position. Here the delay imposed by the capacitor **98** again will permit the beam to come to rest before being punched, thereby preventing damage to the punch unit **16**. However, the chance of the servo amplifier failing before that of the power supply is so remote as to be negligible. Internal fusing is more apt to open circuit the power supply. In the event of power supply failure, even though amplifier **68** is still operable it is without power, the contacts of relay **94** will not close and the punch unit **16** therefore will not be actuated.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. Apparatus for punching an elongated member, said apparatus comprising, in combination: ways along which said member travels, a guide extending along said ways, a carriage engaging said guide for movement therealong, a punch unit extending across said ways and adapted to punch said member, means on said carriage for gripping an end of said member, program means for setting up punching instructions in digital form, said program means electrically connected to a servosystem, said servosystem traversing said carriage along said guide to position said member along said ways in response to said instructions, detecting means emitting a signal when said member has finally come to rest in a position in accordance with said instructions, means for initiating operation of said punch unit in response to said signal, said detecting means including switching means having a pair of control terminals and operable at a given potential between said control terminals corresponding to the maximum positional error of said servosystem, means generating a unidirectional voltage which is a function of the magnitude of the positional error of said member, and an integrating circuit coupling said voltage to said terminals so as to delay the appearance of said potential at said control terminals until said member has finally come to rest.

2. The combination defined in claim 1 in which said detecting means includes means generating a unidirectional voltage between a first terminal and a common reference point, said voltage being a function of the magnitude of the positional error of said member, a unidirectional voltage source connected between a second terminal and said common point, a voltage divider connected between said first and second terminals, the polarity at said second terminal with respect to said common point being opposite that at said first terminal, a tap on said voltage divider, switching means having control terminals connected between said tap and said common point and integrating means arranged to make changes in the voltage between said control terminals lag changes in said positional error.

3. The combination defined in claim 1 including means for generating a voltage corresponding to the position of said member indicated by said instructions, means for developing a voltage corresponding to the actual position of said member, means comparing said voltages to provide an error signal, and a motor connected to traverse said carriage in response to said error signal.

4. Apparatus for punching an elongated member, said apparatus comprising, in combination, ways along which said member travels, a pair of rails extending along said ways on opposite sides thereof, a carriage riding on said rails, a punch unit extending across said ways, said punch unit having punches adapted to form in said member a plurality of holes disposed transversely with respect to each other on said member, a gripper carried by said carriage for gripping an end of said member, said gripper having a reference surface abutted by said end to locate said end with respect to said carriage, a recording medium carrying punching instructions in digital form, said instructions including the locations of holes along said member and the designation of which of said punches are to be actuated at each of said locations, means for reading said digital instructions, means for generating a first voltage corresponding to said locations along said member, sensing means providing a second voltage corresponding to the position of said member along said ways, means for comparing said first and second voltages to derive a positional error voltage, means for amplifying said error voltage, a hydraulic motor coupled to said carriage to move it along said rails, a valve controlling the flow of fluid to said motor in accordance with the amplified error signal, actuating means controlling the punches in said punch unit in accordance with said instructions, and means responsive to said error signal for initiating operation of said actuating means when said signal has decreased below the value corresponding to the maximum positional error of the system for a sufficient time to insure that said member has come to rest in a position in accordance with said instructions.

5. The combination defined in claim 4 including a rack connected to said carriage and extending parallel to the direction of travel thereof, said hydraulic motor having a first pinion meshing with said rack to drive said carriage, said sensing means including a second pinion meshing with said rack and means for generating a voltage which is a function of the angular position of said second pinion.

6. The combination defined in claim 5 in which said initiating means includes switching means having a pair of control terminals and operable at a given potential between said control terminals, means generating a unidirectional voltage which is a function of the magnitude of said error signal, and an integrating circuit coupling said voltage to said terminal.

7. The combination defined in claim 5 in which said recording medium is a punched card, each row of holes on said card containing a set of instructions for the punching of holes at a location along said member and including means for indexing said card to the next set of instructions upon completion of each punching operation.

8. A servo-positioning system comprising, in combination, means generating a voltage corresponding to the desired position of an object, sensing means generating a voltage corresponding to the actual position of said object, means for comparing said voltages to provide an error voltage, means for amplifying said error voltage, drive means for moving said object in response to the amplified error voltage in such manner as to diminish said error voltage, and null indicating means including means developing a unidirectional voltage between a first terminal and a common reference point, said unidirectional voltage being a function of the magnitude of said error voltage, a unidirectional voltage source connected between a second terminal and said common point, a voltage divider connected between said first and second

terminals, the polarity of said first terminal with respect to a common point being opposite to that of said second terminal with respect to said common point, said voltage divider having a tap, switching means having a control terminal connected between said common point and said tap, and delay means arranged to make the changes in the voltage between said control terminals lag the changes in said error signal.

9. The combination defined in claim 8 in which said switching means includes a transistor having an emitter, a base and a collector, a normally open relay having a coil connected in series with said voltage source between said emitter and said collector, means connecting said base to said tap, and a capacitor connected between said tap and said common point, the direction of base-emitter conduction of said transistor being in accordance with the polarity of said second terminal.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,165,952 January 19, 1965

Thomas W. Thompson et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, lines 42, 58 and 71, and column 5, line 2, for "valve", each occurrence, read -- value --.

Signed and sealed this 24th day of May 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

UNITED STATES PATENT OFFICE

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