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[54] **ELECTROSTATIC COATING OF METAL POWDER ON METAL STRIP**

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Related U.S. Application Data

[60] Division of Ser. No. 63,896, Aug. 14, 1970, Pat. No. 3,745,034, which is a continuation of Ser. No. 660,787, Aug. 15, 1967.

[52] **U.S. Cl.** **118/621,** 118/627, 118/630

[51] **Int. Cl.** **B05c 5/02**

[58] **Field of Search** 118/621, 627, 629, 630, 118/631, 634; 117/93.4

[56] **References Cited**

UNITED STATES PATENTS

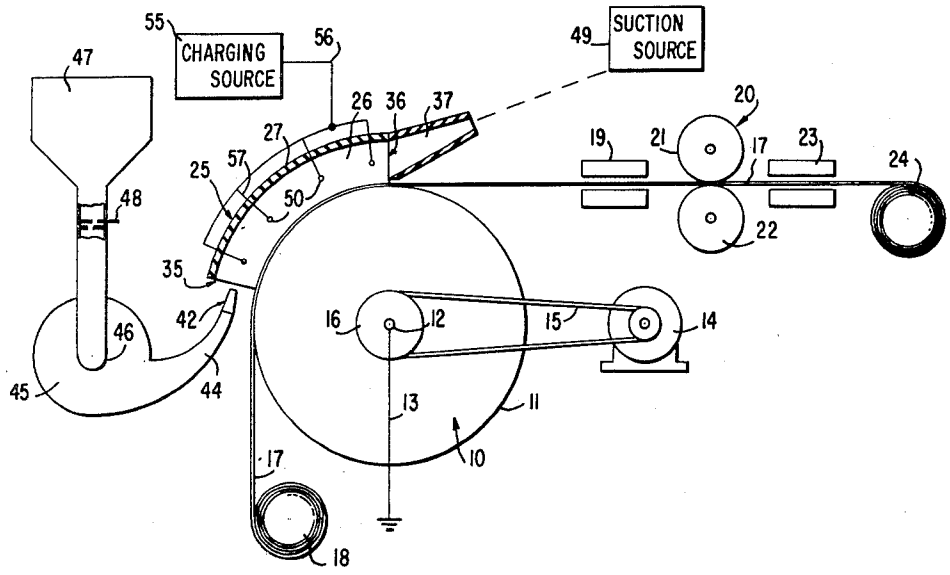
2,097,233	10/1937	Meston	118/629
2,191,827	2/1940	Benner et al.	118/630
2,352,252	6/1944	Canetta	118/630
2,753,796	7/1956	Wood et al.	118/627
2,796,845	6/1957	Rendel	118/634
2,815,734	12/1957	Carlson	118/630
2,888,362	5/1959	Starkey	118/630
3,000,752	9/1961	Jackson et al.	118/627
R22,419	1/1944	Smyser	118/630

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Assistant Examiner—Leo Millstein

[57] **ABSTRACT**

An apparatus for applying a metallic coating on metal strip, particularly steel strip, by electrostatically depositing on the strip a uniform layer of metal powder and thereafter subjecting the strip and the layer of metal powder to heat treatment and then compaction to effect cohesion of the particles of metal powder and adhesion of the metal particles to the strip.

1 Claim, 4 Drawing Figures



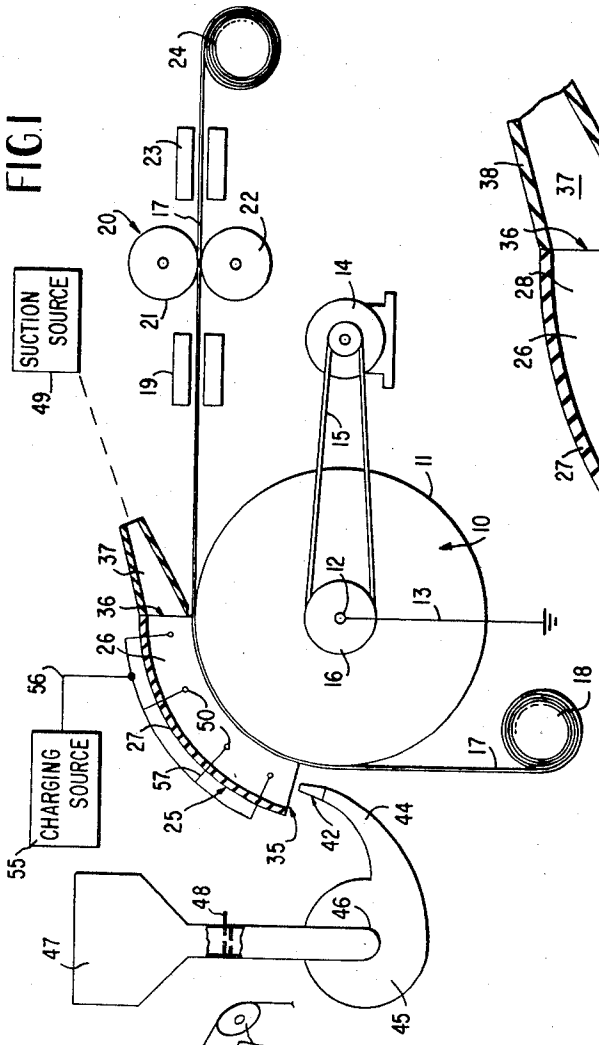


FIG. 1

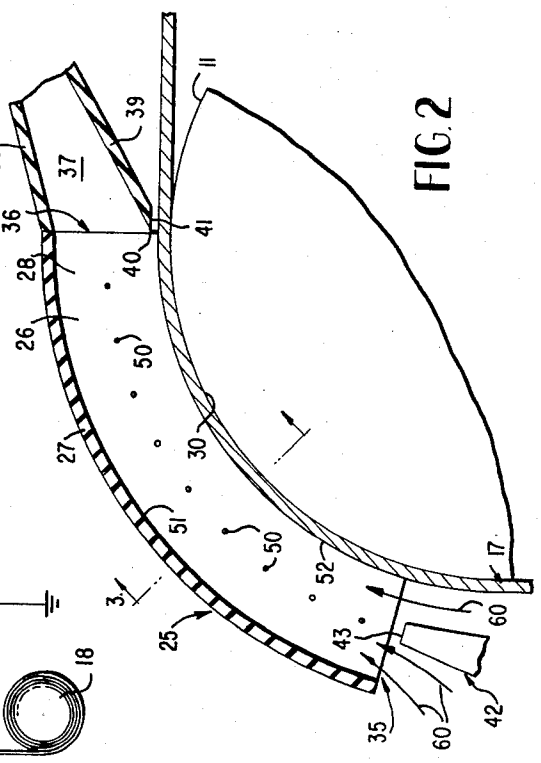


FIG. 2

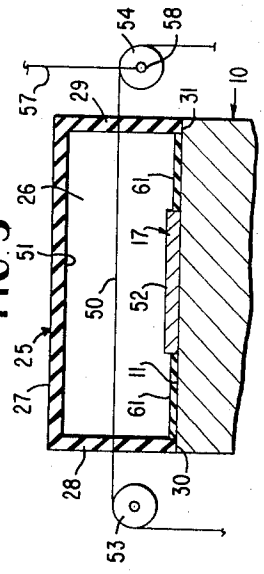


FIG. 3

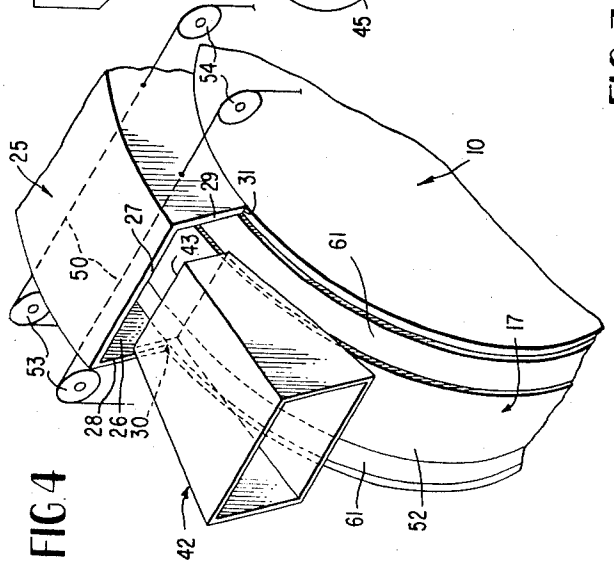


FIG. 4

ELECTROSTATIC COATING OF METAL POWDER ON METAL STRIP

This is a division, of application Ser. No. 63,896, now U.S. Pat. No. 3,745,034, filed Aug. 14, 1970, which, in turn, is a continuation of application Ser. No. 660,787, filed Aug. 15, 1967.

RELATED APPLICATION

Application Ser. No. 534,420, filed Mar. 15, 1966, now U.S. Pat. No. 3,485,654 — Leslie D. McGraw, Robert B. Reif – METHOD OF PREPARING METAL COATED METALLIC SUBSTRATES AND THE RESULTANT PRODUCTS.

BACKGROUND OF THE INVENTION

This invention relates to apparatus for applying a metal coating on metallic strip by electrostatically depositing metal powder on the strip.

In the past, metallic coatings have been applied to metal objects by the use of electrostatic spraying systems to deposit metal powder on the objects. Such systems employ a spray nozzle for discharging an aerosol of metal powder and a gas, such as air, and include high voltage electrodes placed in or near the nozzle to effect charging of the particles of metal powder. The discharge from the nozzle is directed toward the object to be coated which is maintained at a polarity opposite the polarity of the electrodes to establish an electrical field which moves the charged particles of metal powder toward and onto the surface of the object. Attempts to use such electrostatic spraying systems for applying metallic coatings on metal strip have not produced a commercially acceptable process.

It is an object of the present invention to provide a novel an apparatus for coating metal strip with metal powder by an electrostatic process.

Another object is to provide an apparatus of the foregoing character which overcomes the disadvantages of the prior systems and provides a commercially acceptable process.

Still another object of the present invention is to provide a novel an apparatus for electrostatically coating metal strip with metal powder in a continuous process.

A still further object is to provide a novel apparatus which overcomes electrical shorting problems associated with electrostatic coating systems employing conductive particles.

Other objects and features of the invention will appear from the following detailed description considered in connection with the accompanying drawing which discloses one embodiment of the invention. It is to be expressly understood, however, that the drawing is designed for purposes of illustration only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

SUMMARY OF THE INVENTION

Apparatus for applying metallic coating on metal strip by discharging a cloud of metal powder into a chamber through which the metal strip moves and in which the metal powder is electrostatically deposited on the metal strip, and apparatus for overcoming the problems of electrical shorting of the electrostatic deposition system attendant the electrostatic deposition of metal powder on metal strip.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing, in which similar reference characters denote similar elements throughout the several views:

FIG. **1** is a diagrammatic view in side elevation and partially in section of a coating apparatus provided by the present invention;

FIG. **2** is an enlarged fragmentary view, partially in section, of a portion of the apparatus shown in FIG. **1**;

FIG. **3** is a view in section taken along the line **3—3** of FIG. **2**; and

FIG. **4** is a three-dimensional view of the part of the apparatus shown in FIG. **2.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference more particularly to FIG. **1** of the drawings, a coating apparatus provided by the present invention is shown therein including a cylindrical drum **10** having an outer cylindrical metallic surface **11.** The drum **10** is mounted on and rotates with a shaft **12** supported by suitable bearings, not shown, and, for a purpose that will be described below, the outer cylindrical surface **11** is maintained at ground potential such as by lead **13** connected to the shaft **12.** The drum **10** is rotated in a clockwise direction by means of a variable speed motor **14** driveably connected to the drum by belt **15** and pulley **16.** Metallic strip **17** to be coated, such as steel strip, previously treated by any suitable conventional chemical process to present an impurity-free surface, is delivered from an uncoiler **18** and guided by conventional guide rolls, not shown, for movement along a path including contact with a portion of the surface **11** of the drum **10** and then through a furnace **19,** a compaction mill **20** including rolls **21** and **22,** and a furnace **23,** to a coiling device **24.** The coiling device **24** maintains the strip under tension in a conventional manner and the drum **10** is rotated in the direction of strip travel and at such a speed so that there exists slight, if any, relative movement between the strip **17** and the outer cylindrical surface **11** of the drum.

The apparatus further includes a structure **25** forming a coating chamber **26** through which passes the strip material when in contact with the outer cylindrical surface **11** of the drum **10** and wherein a surface of the strip receives a uniform coating of particles of metal powder in a manner described below. As shown more particularly in FIGS. **2** and **3** of the drawing, the structure **25** includes a housing having a top wall portion **27** and depending side wall portions **28** and **29** formed of nonelectrically conductive material. The top wall portion **27** overlies and is parallel to a segment of the surface **11** extending throughout the width of the roller **10** on which the strip **17** is supported and the free edges **30** and **31** of the side wall portions **28** and **29,** respectively, are concavely curved to correspond to the curvature of the surface **11** for close sliding contact with opposite marginal side portions of the cylindrical surface **11.** The structure **25** is supported on a stationary portion of the apparatus, not shown, to maintain the above-described relation with the drum and strip as shown in the drawing; detachable clamping means may be employed to permit movement of the structure away from the drum. The wall portions **27, 28** and **29** and the outer surface **11** of the drum **10,** overlied by the top wall portion **27,** define the coating chamber **26** which

extends transversely of the drum **10** between the side wall portions and angularly thereof throughout the portion of the cylindrical surface **11** in contact with the strip **17.**

For a purpose that will be described below, the entrance opening **35** of the chamber **26** is substantially unrestricted, that is, of a cross-sectional area corresponding to the cross-sectional area of the chamber at any plane along its length, and the exit opening **36** communicates with a discharge chamber **37** defined by a housing of non-electrically conducting material including top wall **38** and lower wall **39.** The inner transverse edge **40** of the wall **39** terminates in spaced parallel relation with the cylindrical surface **11** to provide a slot **41** through which the strip passes on its way from the chamber **26.**

A discharge nozzle **42** is located forward of the entrance opening **35** intermediate the sides of the cylindrical surface **11** and has a discharge opening **43** facing in a direction toward the entrance opening, the discharge opening being of substantially rectangular shape and positioned with its length dimension in spaced parallel relation to the surface **11.** The nozzle **42** is connected by conduit **44** to the discharge of a blower **45.** The blower may be of conventional construction having an air inlet, not shown, and a metal powder inlet **46** fed from a hopper **47** containing metal powder. Any suitable means such as an adjustable slitted plate-type valve **48** is provided for controlling the flow of metal powder to the blower. The blower delivers an aerosol, comprising particles of metal powder suspended in air, which is fed to the nozzle **42** and discharged from the opening **43** as a cloud of metal powder in a direction toward the entrance opening **35** and into the chamber **26.** The discharge chamber **37** is connected to a source of suction **49** to induce the flow of powdered metal through the chamber.

A plurality of charging wires **50** are located in the chamber **26** in spaced relation relative to the direction of movement of the strip **17** and are each disposed transversely of the strip and parallel to the longitudinal axis of the drum **10** and in spaced relation with the inner surface **51** of the top wall portion **27** and the outer surface **52** of the strip **17.** The charging wires **50** pass through suitable openings in the side wall portions **28** and **29** and, as shown in FIGS. **3** and **4,** are supported outside the chamber **26** on opposite sides of the wall portions **28** and **29** by rollers **53** and **54,** respectively. The charging wires beyond the rollers are connected to any suitable reeling and unreeling mechanism, not shown, for periodically moving different portions of the charging wires through the chamber **26** for reasons that will be described below. The charging wires **50** are connected to a source **55** of high potential by common conductor **56** and individual conductors **57.** If desired, the individual conductors **57** may be connected to respective charging wires by a connection to an insulated, conductive supporting shaft **58** for conductive rollers **54** as shown in FIG. **3.**

As mentioned above, it is one of the objects of the present invention to provide an electrostatic coating apparatus including means which overcomes the electrical shorting problems attendant the electrostatic coating of metal strip with conductive powder. Such means includes the provision of the charging chamber **26** having an entrance opening **35** in combination with the metal powder discharge nozzle **42** including a discharge opening **43** of a cross-sectional area substantially less than the cross-sectional area of the entrance opening **35.** This arrangement permits the flow of air around the discharge nozzle and through the entrance opening and into the chamber as indicated by arrows **60** of FIG. **2;** the inflow of air being induced in part by the discharge from the nozzle and in part by the slight suction operating upon the discharge chamber **37.** The flow of auxiliary air through the chamber **26** sweeps from the chamber particles of metal powder not deposited on the strip and minimizes the deposition of metal powder on the inside surfaces of the wall portions defining the chamber and prevents accumulation within the chamber of large masses of metal powder that could result in shorting the charging wires. The foregoing means also includes the feature of spacing the surface **52** and the edges of the strip from the inner surfaces of the structure **25** a distance greater than the distance between the charging wires **50** and the surface **52** of the strip. As seen more clearly in FIGS. **3** and **4,** the transverse dimension of the strip **17** is substantially less than the transverse dimension of the chamber **26** and the strip is centered transversely of the chamber with bands **61** of non-conducting material positioned on the portions of the cylindrical surface **11** between the edges of the strip and the side wall portions **28** and **29.** The chamber **26** extends in the direction of strip movement a distance sufficient to provide the deposition of the desired coating under given conditions of variables including for example strip speed and powder cloud density.

In operation, high potential from the charging source **55** is applied to the charging wires **50** to produce corona about the wires throughout their length within the chamber **26.** The resulting intense ionization of gas molecules about the charging wires produces a large number of ions. The ions of a polarity opposite that of the charging source are attracted to the charging wires and neutralized while ions of the same polarity as the charging source are repelled from the charging wires. The high potential applied to the charging wires also produces, since the strip **17** is maintained at the opposite polarity, an electrical field between the charging wires and the surface **52** of the strip and the ions of the same polarity as that of the charging source are propelled by the electrical field in a direction toward the strip surface. At the same time, the blower **45** produces an aerosol of metal powder suspended in air which is discharged from the nozzle **42** as a cloud of metal powder particles which passes through the entrance opening **35** into the region of the chamber **26** between the charging wires **50** and the surface **52** of the strip; the particles of metal powder moving through the chamber **26** in a direction toward the exit opening **36** concurrently with the direction of movement of the strip. The particles of metal powder move through the path of the ions propelled from the charging wires and are charged by ion bombardment. Movement of the metal powder particles so charged is influenced by the electrical field and the charged particles within the field are accelerated in a direction toward and impinge upon and collect on the surface **52** of the strip. Such charging of the metal powder particles and their deposition on the surface of the strip by the electrical field occurs substantially throughout the chamber **26** and the strip leaves the chamber through the slot **41** uniformly coated with metal powder. Particles of metal powder which are not

charged or which are otherwise not deposited on the surface of the strip are swept from the chamber **26** into the discharge chamber **37** due to the flow of air into the entrance opening **35** and through the chamber **26.** Such action, as noted above, minimizes accumulations of metal powder on the inside surfaces defining the chamber **26** and precludes the formation of conductive paths which would effect shorting of the charging wires and interruption of the charging and deposition processes. Also, the charging wires **50** are continuously moved transversely of the chamber **26** to prevent the accumulation of metal powder on the charging wires. Such accumulation would increase the strength of the electrical field in the region of the accumulation and produce non-uniform deposition of metal powder on the surface of the strip. If desired, the discharge chamber **37** may be connected to a system for recovering undeposited metal powder and for returning the powder to the hopper **47.** The metal strip having the coating of metal powder thereon leaves the charging chamber **26** through slot **41** and then passes through the furnace **19** to effect heat treatment of the strip and metal powder for efficient compaction in the compaction mill **20.** The combined function of the furnace **19** and the compaction mill **20** effects cohesion between the particles of metal powder and adhesion between the metal particles and the surface of the strip, and the coated strip from the compaction mill **20** may be passed through furnace **23** for further heat treatment and then coiled on the coiling device **24** or fed to another line for further processing. If desired, the coated strip leaving the compaction mill **20** may not be subjected to further heat treatment in the furnace **23** prior to recoiling or further processing.

Apparatus embodying the principles of the present invention has been successfully operated to coat steel strip with aluminum. The steel strip was 1 mil thick and 4 inches wide and was centered on the drum between the side wall portions defining the coating chamber; the side wall portions were spaced by about 20 inches and the exposed side portions of the cylindrical surface of the drum were masked with mylar. Four charging wires, comprising 0.005 inch diameter stainless steel wires, were mounted in the charging chamber transversely of the strip in the manner shown in the drawing. In operation of the apparatus, the following conditions existed:

Metal Powder:	Atomized aluminum having a mean mass particle size of 5 microns
Metal Powder Feed Rate:	21–26 grams per minute
Charging Voltage:	13–15 kv.
Strip Speed:	7.5 feet per minute
Pre-Compaction Heat Treatment:	Temperature, about 850°F.; time, 1 to 2.5 minutes
Compaction:	Reduction rolling; about 0.8% elongation
Post-Compaction Heat Treatment:	Temperature, about 950°F.; time, 0.5 to 2.5 minutes

The strip leaving the coating chamber had deposited on its upper surface a uniform layer of aluminum powder and possessed good green strength. Following the pre-compaction heat treatment, compaction and post-compaction heat treatment, the aluminum coating on the steel strip was found to possess good coherence and adherence; and the thickness of the aluminum coating was about 0.1 mil. During operation of the apparatus, there was no appreciable accumulation of metal powder within the charging chamber and the operation was not inhibited by electrical shorting of the charging system.

It is to be understood that the gaseous carrier forming the aerosol of metal powder may comprise air, as described above, or an inert gas. Also, the auxiliary gas flowed into the entrance opening and through the charging chamber **26** may comprise air, as described above, or an inert gas. When the auxiliary gas comprises an inert gas, an inert gas supply duct would be attached to the opening **35** of the chamber **26** and the discharge nozzle **42** would pass through a wall of the supply duct with its discharge opening **43** located within the supply duct and positioned relative to the entrance opening of the chamber **26** generally in the manner shown in FIG. **2.**

The novel features provided by the present invention which overcome the electrical shorting problems attendant the electrostatic deposition of metal powder on metal strip may be used in electrostatic coating apparatus operating in processes which may differ from the process disclosed herein and described above and may be used for applying metal coatings, in place of aluminum as described above, on strip material formed of other metals in addition to steel, as described above. For example, metal powder having a mean mass particle size greater than **5** microns may be used, such as commercially available metal powders of 15 to 30 microns, and the strip before entering the coating chamber may be untreated or treated such as by wetting with water. Also, the temperature of the pre-compaction heat treatment may differ from the foregoing example and the post-compaction heat treatment need not be employed. Accordingly, the foregoing description including the specific examples are for purposes of description only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

We claim:

1. Apparatus for applying a metal powder coating on metal strip comprising

means including non-electrically conductive wall means defining an elongated passageway having an entrance opening and an exit opening,

means for continuously moving metal strip to be coated through the passageway in a direction from the entrance opening to the exit opening and in out-of-contact relation with the wall means,

a plurality of charging wires in the passageway spaced longitudinally of the passageway in the direction of movement of the metal strip through the passageway, each charging wire extending transversely of the passageway and of the metal strip moving through the passageway,

a charging circuit for the charging wires including the metal strip and a source of charging potential connected to the charginig wires,

means for supplying a stream of carrier gas,

means for holding a supply of metal powder,

means for controlling flow of the metal powder from the last claimed means,

means for flowing metal powder from the supply into the carrier gas to suspend metal powder in the carrier gas to form a cloud of metal powder,

means for introducing the cloud of metal powder into the entrance opening of the passageway generally in the direction of the movement of the strip through the passageway, with metal powder sus-

pended in gas passing between the charging wires and the metal strip, and

means including a source of gas suction for withdrawing metal powder suspended in gas at a point contiguous to the strip exit end of the passageway,

the means for introducing the cloud of metal powder into the entrance opening including

nozzle means located contiguous to the entrance opening and having a discharge opening facing in the direction of the entrance opening,

the cross-sectional area of the nozzle at its discharge end being substantially less than the crosssectional area of the entrance opening of the passageway,

means for feeding the metal powder suspended in the carrier gas to the nozzle means,

the relative shapes and dimensions of the nozzle means at the discharge end and the entrance opening of the passageway, acting with the source of gas suction, causing the carrier gas and suspended metal powder to induce ambient air to flow into the entrance opening.

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