

Oct. 28, 1969

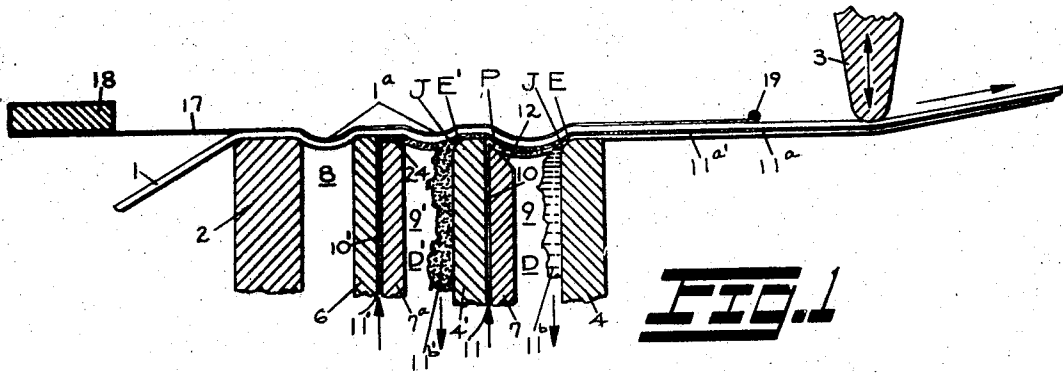
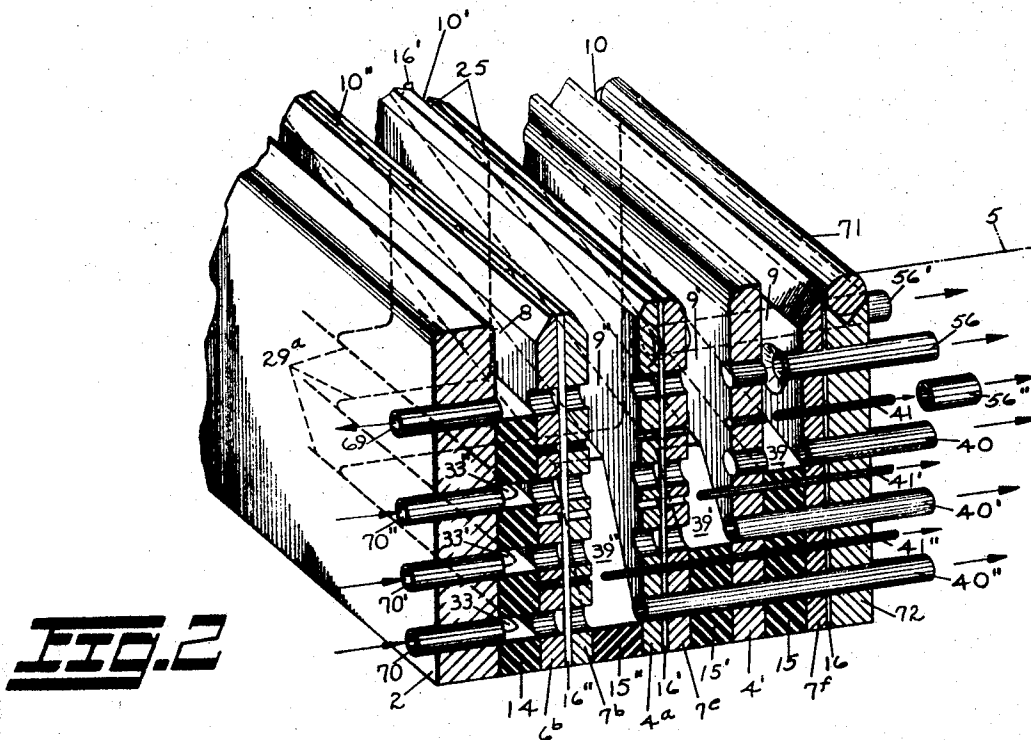
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3,474,757

MULTIPLE COATING APPARATUS

Filed Oct. 24, 1965

2 Sheets-Sheet 1



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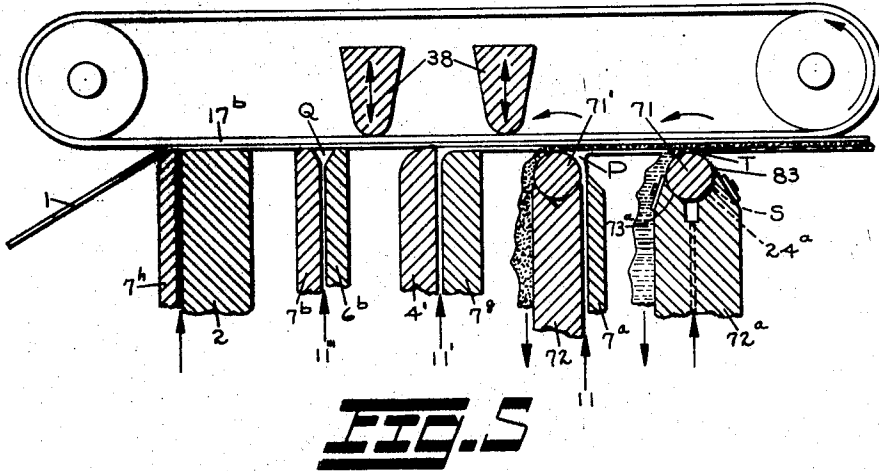
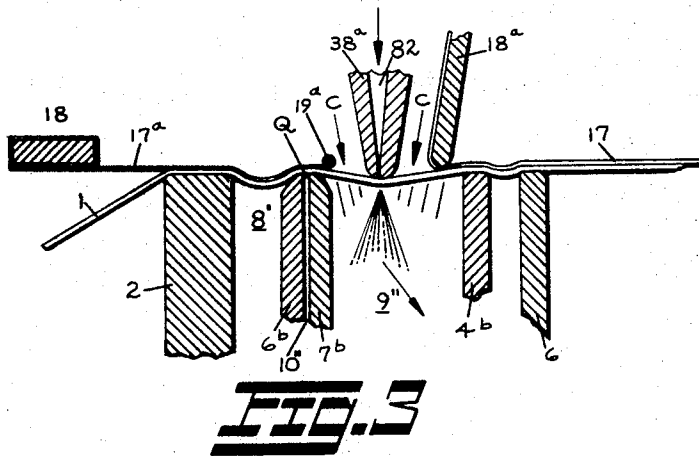
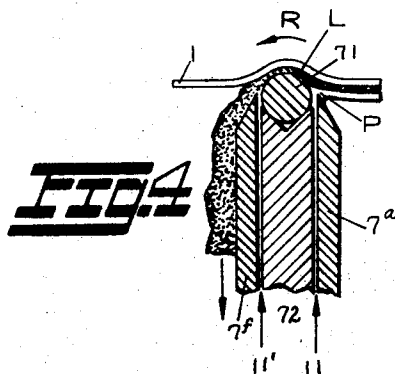
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2 Sheets-Sheet 2



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MULTIPLE COATING APPARATUS

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7 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for applying a plurality of fluid substances to paper in concatenate sequence, including treatment, impregnation and coating. Various fountaining techniques are utilized in combination with subatmospheric pressure differentials to control depth of penetration and superficial thickness by means of partial removal of conjunct fluid substances. The invention also discloses rotating rod applications involving disparate substances, including techniques for interfacial admixing, lubricating and bead coating.

CROSS REFERENCES TO RELATED APPLICATIONS

This application includes subject matter closely related to that which is disclosed in my application Ser. No. 504,405, filed concurrently Oct. 24, 1965; a third application, Ser. No. 504,445, also filed Oct. 24, 1965, discloses subject matter related in part to this application.

This invention relates to methods and apparatus for coating continuous webs of flexible material such as paper, film and the like, and more particularly relates to improvements by which such a web may be treated, impregnated or surface coated plurally in almost instant sequence. The improvement basic to such accomplishment is described in my U.S. patent application, which is first above identified.

In the above identified patent application, there is disclosed new and novel means by which spreading force may be more reliably and uniformly applied oppositionally to a doctoring element. Essentially the method involves positioning the doctoring element in planar, rather than deflective, tensional engagement with the web and the development of spreading force as a function of differential air pressure operative against the web, this being accomplished by maintenance of subatmospheric pressure within the coating enclosure of which the downweb boundary comprises the doctoring element, over which the web and a deposited layer of coating composition are drawn and against which they are impinged by atmospheric pressure. By such means and positioning, web tension is sinally nullified as a primary factor affecting coating weight, thereby permitting the efficient coating of diverse product and the control of coating weight within critical tolerances. By the inclusion of additional pairs of selective fountaining and doctoring elements, diverse sequence applications are made possible.

The primary object of the present invention, therefore, is to apply the aforesaid teachings to the plural treatments of such webs, including there among web pretreatment and/or impregnation, high-solids filling of cavitous surfaces, and laminar applications of wet-on-wet coatings.

Another objective includes several species of application techniques involving the handling or utilization of dissimilar compositions or substances in contact with a rotating doctoring element.

In addition, the list of objectives included in the first above identified patent application are similarly applicable to the present invention.

A fuller understanding of the various means by which

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these objectives may be accomplished will be gained by reference to the accompanying drawings, in which reference characters are comparable to those of the first identified accompanying application.

FIGURE 1 is a sectional elevation showing primary coater elements arranged for laminar application of two wet-on-wet coatings.

FIGURE 2 is a perspective view through the medial section of a three stage coater assembly.

FIGURE 3 is a medial part end elevation showing an arrangement of upweb coater elements whereby a traveling web may be transiently impregnated and the impregnant controllably extracted therefrom.

FIGURE 4 is a part elevation in section showing the fountaining of two coating compositions against opposite sides of a rotating doctoring element.

FIGURE 5 is an end elevation in section showing an arrangement of coater elements capable of high-solids filling of a cavitous surface followed by application of three wet-on-wet coating layers.

The apparatus arrangement illustrated in FIGURE 1 includes six bars or plate sections 2, 6, 7a, 4', 7, 4, each in spaced and parallel standing relationship to those adjacent, over which assembly passes the traveling web 1. Vacuum chambers 8, 9', 9 occupy the indicated spaces between alternate pairs of plate sections 2-6, 7a-4', 7-4 and fountaining channels 10', 10 are developed between intermediate pairs of plates 6-7a, 4'-7. Patterned inserts 14, 15', 15, 16', 16 of rubber sheeting or suitable gasketing complete the indicated chambers 8, 9', 9 and channels 10'; 10 and permit compressive lockup of the assembly as described in the accompanying patent application first identified. The web 1 spans the top face of the assembly in perfect planar relationship with the downweb support 3, and is suspended across the several vacuum chambers 8, 9', 9 into each of which it may deflect from its tensioned plane 5 to the extent induced by subatmospheric pressure differential and permitted by tension and inherent stiffness. A pliant membrane 17 attached to an upweb anchorage 18 and drawn frictionally downweb may overlay the web 1 and the coater assembly, thus completing closure of the several vacuum chambers 8, 9', 9 and transiently sealing the outer surface of the traveling web 1.

The first or base coating composition 11' is fed through the upweb channel 10' and against the web; thence drawn through fluted ducts 24 formed in the top edge of the fountaining plate 7a and into metering contact E' with the radiused doctoring element 4', the excess composition 11b' cascading downward along the upweb face of the doctoring element. The second or top coating composition 11 is bead fountained P against the first metered coating, its application thereto being nonpressurized at its point of contact by provision for clearance between the vacuum-deflected web 1a and the lowered and beveled edge 12 of the bead-fountaining plate 7, the applied top coating 11 thence drawn by the traveling web through the final metering restriction E against the downweb doctoring element 4.

The indicated choice of fountains and their positioning in this particular arrangement is purposeful since the fluted fountain 7a, 24 positioned upweb is capable of pressurization by adjustment in flow rate, thereby providing additional inducement for web penetration by the base coating if desired, whereas the bead fountain 4, 7 positioned downweb permits laminar flow and thus is ideally suited to overlay its effluent with least fluid disturbance. Thus, the motivation for the illustrated arrangement was to apply laminar coatings, it being further conducive toward such end that (a) the overlaid composition be the lesser viscosited, (b) less spreading force

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be applied thereto, and (c) its doctoring radius be increased. Of these three factors the first is the most significant, and the last perhaps the least. It further will be realized that having met the first requirement, the second tends to follow and the third is unnecessary.

Various means by which penetration of the surface coating may be controllably induced into a porous or semiporous web are described in the first accompanying application, which in brief comprises prerarification of web-entrained air and additional inducement by means of pressurizing the fountaining of the composition thereto. For the purpose of clarity in description, *penetration* as thus defined will be differentiated from *impregnation*, the latter herein implying containment of the composition within the web per se with no more than superficial coating of the web surface being involved. Although the arrangements shown in FIGURES 1 and 2 are capable of either result, depending in large measure upon fluidity of the coating first applied and web receptivity therefor, the first showing was intended to be exemplary of penetration.

The three stage assembly shown in FIGURE 2 therefore will be used to illustrate an arrangement suitable for an impregnating application followed by two overlaid coatings, of which the first could indeed include penetration, such being indicative of the versatility of the present invention.

FIGURE 2 shows the central portion of a three stage assembly in which the first and second coating compositions may be pressurably fountained Q in spaced upweb relationship to their respective doctoring elements 4a, 4', the third composition being fountain nonpressurably P adjacent the rotatable doctoring element 71 and thus downweb from its controlling vacuum chamber 9. Its downweb positioning in this instance is for the purpose of descriptive showing of the total assembly, it being further indicative, however, of choice in positioning such an element. Also shown are different doctoring elements, the first 4a having a beveled impingement, the second 4' radiused and the third 71 rotatable.

The drawing further illustrates the interrelation of the various parts of a typical assembly, including the several inserts 14, 16'', 15', 16', 15', 16, 15 which complete the basic structure and form the various contours within the spaces indicated in each of the other drawings. In this showing it will be apparent that the essential porting of the basic or metal elements may be duplicative, thereby permitting interchangeability and positional selection in great variety of combinational arrangements, although each element in itself is capable of a high degree of specialization. The basic porting as shown is three-positional with respect to input 70, 70', 70'' and drain lines 40, 40' 40'', there being included individual ducts for gaseous exhaust 56, 56', 56'', 69 from the several vacuum chambers 8, 9, 9', 9'' and means for liquid level control 41, 41', 41'' of drainage rate from each sump 39, 39', 39''. This particular assembly is designed for orificed distribution, including an unobstructed crossweb duct 33, 33' 33'' for each of the compositions, with distributive and equal portions thereof meterably orificed into the base of each feed channel or individually into pockets 25 patterned in the respective inserts, typical flow lines 29a showing in the drawing. It will be apparent that the first upweb fountaining plate 6b may contain all the described orifices, or that each row of orifices may be insertable into a suitable recess similarly positioned, thereby permitting selectivity and simple interchangeability thereof and the use of clearing and shutoff plungers installed in the main support bar as described in my accompanying application first identified.

It is interesting to note that the basic three-positional porting arrangement shown is capable of handling double that number of sequential stages by inserting upweb from the indicated set of fountaining and doctoring elements three additional pairs of selected elements symmetrically

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positioned with respect to the depth of the several sumps and the indicated vacuum and liquid level connections, all of which is easily made possible by providing dual inputs (70) for each composition so that each supplies only half the coater width, three divided pairs of inputs being positioned in the main upweb supporting bar 2 and segmentally crossweb distributed in the first upweb or prevacuuming insert 14 and the remaining three pairs of inputs (70) positioned in the last downweb plate section 72 which in the illustration supports the rotatable doctoring element 71, half crossweb ducts (33) therefor being formed in the lower portion of the last downweb vacuum chamber insert 15. Thus, by suitable porting arrangements, together with precision alignment dowels and clamping bolts, thereby permitting unlimited interpositionability of specialized basic coater elements, such as apparatus is made exceedingly versatile, surprisingly simple and unbelievably compact.

Within the fountain category there also is great variety, ranging from the bead fountain 7 wherein web contact may be established at subatmospheric pressure, or with similar beveled 12 construction but having reduced clearance to the web, being capable of pressure increase. Similarly the fluid fountain 7a is capable of a range of pressurization which may be controlled by the sizing of the fluted ducts 24 and the rate of flow of the incoming composition. That which is designed for intermediate pressurization is illustrated in the second fountain shown in FIGURE 2 wherein the downweb face of the fountain 7e is positioned in planar relationship to the top face of the coater and its downweb corner radiused. The fluted fountain also may be variously shaped if desired. The fountain 6b, 7b first upweb positioned in FIGURE 2 is illustrative of the injector type which is characterized by positive fluid pressure Q application of the coating composition and capacited for forcible injection directly into the web. The fluid pressure deliverable therefrom may be opposed by vacuum drawdown of the web together with its backup membrane into the adjacent vacuum chambers, in addition to which further advantage from web tension may be gained from the use of overhead suspended bars (38) similarly aiding in forcing the web against the fountain. It further will be apparent that the actual shaping and proportioning of the injector fountain is subject to some latitude, e.g., by narrowing the fountain, thereby increasing proportionately the effect of web drawdown against it, or it may be opened by reversing the indicated bevels 12 (as shown upweb in FIGURE 5) thereby increasing the breadth of the pressurized junction with the web. Thus, although the fluid pressure may be identical and its sealing contact with the web secured, the area of pressurable contact and in consequence thereof the interval of pressurization can be varied. It also will be apparent that the ideal fountain for a specific application may combine in moderation certain of the oppositely inclined features of the several types described and including therewith manipulative behavior such as that associated with troweling and sliding contacts in general.

FIGURE 3 shows an arrangement of coater parts capable of impregnating a web in specific depth and immediately thereafter withdrawing a controllable portion of the impregnant. In order to accomplish such treatment, the web passes over the upweb prevacuum chamber 8', thus rarifying the web-entrained air, the developed subatmospheric pressure level within the web being retained by the indicated segment of the overlaying membrane 17a as it is drawn into contact with the pressurized composition 11'' entering through the injector fountain 6b, 7b, the membrane terminating 19a immediately downweb therefrom so as to expose the upper surface of the web directly to external air C and permit vacuum withdrawal through the porosity of the web of that portion of the impregnant as may be desired. Instead of terminating the membrane at the point indicated 19a, in this instance

it may be continuous across the full face of the coater which may include in following sequence a plurality of additional treatments or coatings, that portion of the membrane which spans the withdrawal chamber being vented or perforated so as to permit external air C to pass through to the web as described. In the illustration a suspended bar 38a is included, which may be used in the manner previously described to secure tensional draw-down of the web against the injector fountain, or it may comprise a forceful injector 82 applied to the outer surface of the web. Such an injector may be used to blow air through the web and thus more positively extract the impregnant, or it may inject gas or vapor therethrough for the purpose of setting the impregnant in filleted position at each intersection among the myriad fibres of the paper web, or it may inject a liquid designed similarly to set or to coagulate that portion of the impregnant which remains. Assuming that the described arrangement is to be used with following stages as previously suggested, a second membrane 17 may be positioned as indicated downweb from the overhead injector 38a.

It will be apparent that the depth of impregnation may be influenced by the degree of rarification within the web, and its quantity controlled by metered flow of impregnating composition delivered by the injector fountain. Following such impregnation, the amount withdrawn becomes a function of the downweb vacuous level and the time interval to which it is subjected to subatmospheric pressure differential, in addition to which further withdrawal may be induced controllably by the overhead injector. Downweb from the injector the web is again subject to differential pressure, which may be utilized to extract injected liquid there retained in the web, it being a simple matter therefor to provide separate withdrawal chambers if needed either to provide different vacuous levels or to separate the effluents. It further will be apparent that additional injectors may be utilized if desired, and that a series of plural treatments may indeed be effected by inclusion of additional elements. Those who are skilled in the art will readily discern that the described apparatus and techniques are applicable to a variety of chemical web treatments and diverse involvements with multiple-part compositions and interactivating systems, including the use of noxious or inert gases when necessary, all of which may be done both safely and economically in apparatus of the character herein described.

FIGURE 4 shows a rotatable rod 71 with coating compositions 11', 11 bead fountained P against its opposite faces, the illustration suggesting prima facie that such fountains may be positioned upon either side of an intermediate doctoring element. If the rod were stationary and manually rotated only upon occasion for purposes of clearing its operative surface, it would simply comprise a convenient substitute for a similarly profiled stationary doctoring element (4). In traditional use, such a rod doctor is little more than such a convenience arrangement, even though it be continuously rotated in one direction or the other, the purpose of rotation generally being to clear its working surface of collected particles or agglomerate and to distribute abrasion uniformly upon its total surface.

But since this particular rod 71 is designed to be continuously rotated in contact with two coating compositions 11', 11 while serving primarily as doctoring element for the upweb composition 11', there arises either a number of problems connected with the intermixing of two compositions being adjacently manipulated between the traveling web 1 and the rotating rod, or a potential for achieving certain useful results. First it should be noted that the only wiping force directly applicable to the upper or working surface of the rotating rod is that of fluid viscosity or pressure. In general it may be assumed that under such conditions the coating composition with the lesser fluidity would be capable of displacing that which is more fluid. Thus if the coating applied upweb 11' were

the more viscous and the rod moderately rotated counter-clockwise R and opposite to the direction of web travel, the rod would doctor the upweb coating quite normally since the more viscous composition 11' would bar the lesser 11 from entry into the restrictive passage L between the fast traveling web and the relatively slow reverse rotation of the doctoring rod.

If however, it were desirable to manipulate the interfacial contact between the two compositions, e.g., to improve the anchorage of one to the other, such manipulation could be induced either by lessening the disproportion between the two viscosities or by increase in surface speed of the reverse-rotating element relative to web flow, or of course by alteration of both factors. It will be apparent that by careful adjustment of these factors, the degree and depth of interfacial manipulation may be easily controlled. Additionally it often is possible by formulative means to alter the wet affinity of one or the other of the compositions for the doctoring element, thereby introducing an additional factor potentially contributive to the desired result.

Carrying this variable affinity concept one step further, it will be apparent that the first-contacting rod-wetting composition occupies potentially the dominating position on the rotating surface. Thus if the downweb composition were capable of wettably lubricating the doctoring rod so as to prevent frictional contact with the upweb composition, the rod would then make physical contact only with the downweb composition without necessarily having precluded the possibility of some interfacial admixture, which in the case of two dissimilar compositions could be even more essential.

Application of the rod lubricating or non-affinitious wetting technique has many ramifications, some of which are apparent and others not immediately reckonable. That which perhaps is first obvious is that frictional drag of the coating composition as it is squeezed by the doctoring element could be reduced significantly, thus affecting behavior within the nip and tending to increase coat weight given the same amount of spreading force. The second direct consequence could be the development of an exceedingly smooth surface by having eliminated any tendency for the departing composition to cling or to string back to the doctoring element. Thus compositions not presently considered smoothable by rotating doctoring means may be made applicable thereto by use of this technique. It will be apparent to those skilled in the art that when lubricating means are utilized, and especially in connection with intermediate placement of such doctoring elements, extreme care must be exercised in the choice of lubricants and in the combinational chemical and physical aspects of the coating compositions with which their use is associated.

The nonaffinitious technique is applicable to margin definition by stripping the margins immediately upweb with a fugitive repellant (such as alcohol solution with a following application of a petroleum-solvated and alcohol-intolerant rubber composition) over which a downweb application of coating composition simply will not spread due to its complete lack of affinity for the wet repellant. In order to assure its non-anchorage, vacuum-induced penetration into the web may need to be avoided by bead fountaining P the coating composition directly into the doctoring nip in the manner in which the final overlaid coating 11 was applied in FIGURE 2. Lateral flowout of the coating composition, at its juncture with the repellant-bearing margins of the web, fails to be drawn into the impingement nip J and falls away in cascade down the upweb face of the fountaining plate 7f. When using ideal combinations of the described character, uncoated stripes or "dry laps" may be developed effectively by this technique, even though the coating composition be fountained in continuous bead across the width of the web.

In addition to being illustrative of purposeful fountain

positioning up or downweb from its associated vacuuous chamber, it further suggests specific utility for stepped pressure differentials by doing that which was avoided in the prior example. Using the apparatus arrangement shown in FIGURE 1 and therein having a higher vacuum D' in the first coating chamber $9'$ than D in the second 9 , the overlaid composition 11 may be induced vacuuously against a transiently nonreceptive undercoating and thereupon doctored to form a continuous overlay, provided of course that the vacuuous inducement and/or the mechanical keying into the interstices of the web were adequate and the composition properly formulated and internally integrated so as not to be separated from its anchorage as it traverses the doctoring element 4 .

Means for lubricating a rotary element are described in the first above identified patent application, a similar element 71 , $72a$ being included herewith in FIGURE 5 in final doctoring position downweb. The types of lubricants may take many forms and often may be specializedly purposed, e.g., they may be fugitive or ultimately serviceable as a slip finish. Similarly they may be miserly wetted upon the rod and repelled by the doctored coating composition, or purposefully depositable upon the coated surface and supplied thereto in relatively copious quantity. In the later instance downweb bead application may be utilized, the running bead being fed by any of several means. One such means is illustrated in the identified doctoring element shown in FIGURE 5, wherein the downweb portion of the bearing socket $73a$ is shallowly grooved in such manner as to form tiny circumferential ducts $24a$ permitting meterable fluid flow S into contact with a leveling blade 83 , the thin layer of fluid therefrom being carried by a reverse-rotating rod into contact with the immediately prior coated traveling web, and thereagainst forming a liquid bead T from which a thin fluid layer is drawn by the departing web.

FIGURE 5 suggests a three stage arrangement including means for high solids filling of a cavitous surface so that overlaid coatings may remain more perfectly planar when dried. This particular arrangement includes a broad injector fountain $7b$, $6b$ for the said filling material $11''$, followed by a troweling action over the spreader $4'$ intended to smooth the filled surface rather than to remove excess material. A modified pressure fountain $4'$, $7g$ therefollowing also incorporates a troweling nip, thence passing over a rotary doctor $71'$ which meters the intermediate coating $11'$ in rod contact with the nonpressured fountaining P of the top coating 11 which is doctored by the final rotating rod 71 which may serve additionally as a bead T applicator for a specialized overcoating if desired.

The overlaying membrane illustrated comprises an endless belt $17b$ which is intended to be driven at web speed or very slightly thereabove, there being optionally included within the belt circuit suspended means 38 for maintaining planar relationship between the moving belt and the top face of the coater. In addition to the normal functions of the overlaying membrane, the driven belt may be used to relieve tension in the web in order to offset the effect of vacuum-induced friction against the top face of the coater. In order to fulfill its total purpose the belt should be wider than the paper web, its consequent frictioning against the outboard ends of the coater being lubricatable by injection of soap solution or other lubricant thereagainst, for which purpose a patternable stripping applicator $7h$ is positioned upweb against the crossweb support member 2 of the assembly.

In addition to the forms previously described, the membranous occluding system may comprise supply and takeup rolls of suitable material suspended over the coater and the connecting web maintained in proper planar relationship therewith by support bars positioned up and downweb therefrom. Such an arrangement permits the working portion of such membrane to be replaced periodically or to be made continuously motionable at a creeping rate, e.g., to cause its total replace-

ment to occur at hourly intervals. Thus far in the development of the invention no such need has arisen, single membranes having served well for several months in light duty service. Occasions develop, however, in which they should be cleaned, such occurrence first giving rise to such a replacement facility.

The coating techniques described are capable of effective performance over a wide range of speed, the upper limit of laminar behavior being definable in terms of Reynolds number or critical velocity, at which point nip behavior will be altered but in no sense inoperable. It will be apparent that suitable flow rates require no more than proper sizing of communicative ducts and the application of adequate upstream pressure, it further being apparent that dwell times often can be offset by increase in pressure differentials and proper application thereof.

By the use of heated coater elements, the described techniques may permit application of heat-liquifiable compositions in plural sequence. It further is suggested that heat-manipulative polymers heretofore considered nonspreadable may indeed be applicable by combination of certain of the techniques described among the several patent applications in the group identified herewith.

To those acquainted with the present status of on-machine coating of printing papers and the like, and cognizant of the many problems associated therewith, the advantages of the present invention will be readily apparent. Even though the art has progressed to include dual wet-on-wet coatings utilizing trailing blade apparatus in tandem, neither the technique nor the equipment is without fault. I believe that certain of these faults may be circumvented by application of the teachings herein disclosed, and that improvement in quality of product and reduction in cost may logically ensue therefrom.

Having thus described my invention, I claim:

1. An apparatus for applying a plurality of fluid substances to a traveling web of paper, said apparatus comprising a concatenation including a plurality of discrete fountains to conjoin said substances consecutively with said web, a plurality of chambers each having an upweb and a downweb boundary to support said web, and vacuuous means coactive with said chambers to effect partial removal of conjunct fluid substances, said fountains and chambers interposed substantially in alternating sequence.

2. The apparatus as claimed in claim 1, wherein a first chamber is positioned to extract air from one surface of said web, a first fountain juxtaposed downweb contiguous said first chamber to inject a first substance impactively into said surface, a second chamber juxtaposed next contiguous said first fountain to effect partial removal of said first substance, and a second fountain superposed over said second chamber to counterinject a second substance pressurably into the other surface of said web.

3. The apparatus as claimed in claim 2, including pliant membranous means conjunct transiently with said other surface, said means extending over said first chamber and fountain.

4. The apparatus as claimed in claim 1, wherein one said boundary comprises a rod having means for continuous rotation.

5. The apparatus as claimed in claim 4, wherein one said fountain is positioned upweb from, and a second said fountain conjoint with, said rod.

6. The apparatus as claimed in claim 5, including precision means for metering the flow of said substance dispensed from said second fountain.

7. In a coating apparatus for applying a fluid substance to a traveling web of paper, said apparatus comprising means for conjoining said substance with one surface of said web, a chamber having upweb and downweb boundaries conjunct with said surface, and means for occluding external air from said chamber, the improvement in said occluding means which comprises, and in combination, a pliant membrane overlaying said chamber and adapted to be conjunct transiently with the other surface of said web,

and wherein said combination includes two rolls, said membrane having an extended length and adapted to be motioned between said rolls.

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