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Seamless Soft Gels...

AN ALTERNATIVE TO CONTRACT MANUFACTURING

by

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ABSTRACT

This paper discusses a method of manufacturing liquid-filled, seamless soft gels without dies. The theory of "drop-formation" is explained as it relates to the production of these products on the GLOBEX MARK II encapsulator.

The advantages and limitations of this manufacturing method are discussed throughout the step by step description of the production process.

All technical as well as economic aspects of the method are explored.

INTRODUCTION

In the United States, soft gelatin capsule or soft gel manufacturing is almost always synonymous with the rotary die process. These machines produce seamed soft gels.

However, for the past 30 years manufacturers in Europe and Asia have been successfully making completely seamless soft gels on another type of machine that requires no dies. This machine is simple to operate and produces extremely high quality soft gels at low cost. Today, over 200 machines of this type are producing soft gels in over 40 countries throughout the world. The machine is the GLOBEX MARK II encapsulator. (Photo "A")

The GLOBEX MARK II encapsulator is manufactured in Holland and has frequently been exhibited at fairs in Leipzig, Moscow, and Posnan, where several gold medals for technological achievement have been awarded. But, up until last April when a fully operational GLOBEX machine was first shown at Interphex U.S.A., in New York, few people in the Western hemisphere had ever heard of this method of producing seamless soft gels.

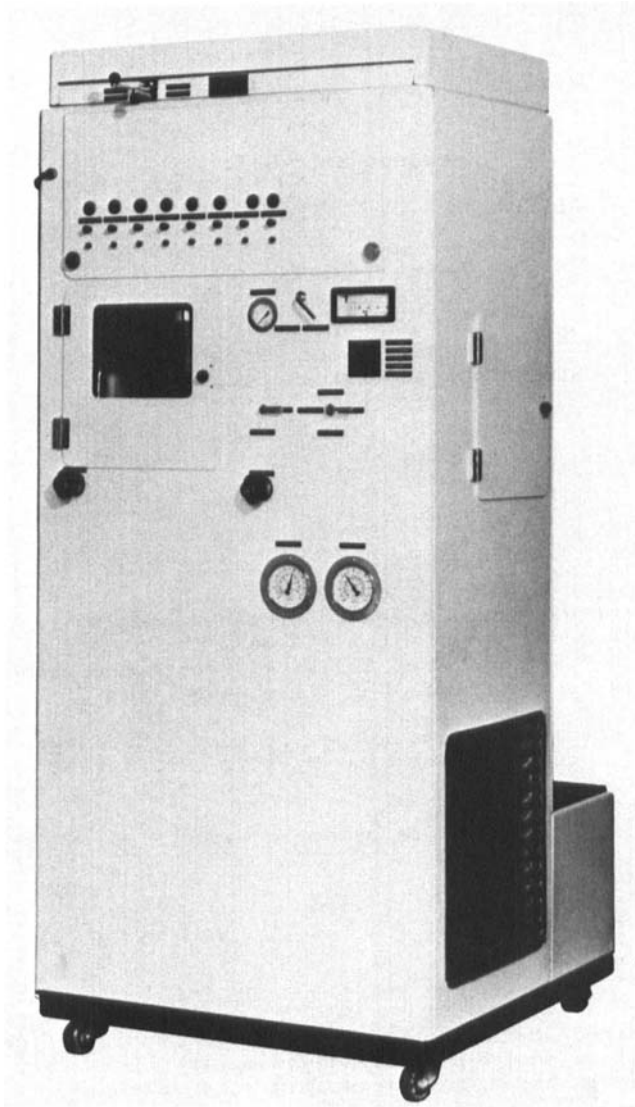

Photo "A". GLOBEX MARK II encapsulator

The GLOBEX MARK II encapsulator allows manufacturers of pharmaceuticals, vitamins, and food supplements an opportunity never before available, to economically self-manufacture soft gels completely in-house.

SEAMLESS SOFT GEL PRODUCTION

The GLOBEX MARK II encapsulator produces seamless soft gels by the "drop formation" method. By employing a fundamental

principle of physical science, namely the tendency of free-falling liquids to form spherical droplets due to surface tension, the GLOBEX MARK II encapsulator produces seamless soft gels that are formed, filled, and sealed instantaneously and continuously.

The production of soft gels by the process which incorporates the GLOBEX MARK II encapsulator consists of the following five steps.

1. Gelatin Preparation.
2. Formation, Filling, & Sealing of Soft Gels.
3. Refrigeration.
4. Cleaning.
5. Drying.

1. Gelatin Preparation

The first step in the successful production of soft gels by this method is the correct preparation of the gelatin solution. The dry gelatin powder is a medium quality, edible gelatin of about 150 Bloom. Either "A" or "B" type gelatin can be used. Glycerine or Sorbitol is added as a plasticizer. Paraben (Paraoxybenzoicacidmethylester) acts as a preservative to increase the shelf life of the finished soft gels. The water used in preparing the gelatin solution should be de-mineralized if high concentrations of Calcium Carbonate are present. There are many possible gelatin formulations which can be utilized in the process. One formulation consists of approximately 36% dry gelatin powder, 12% glycerine, and 52% water. The Paraben weight is less than 1% and is considered negligible. Food grade coloring agents can be added to the water for colored shells. Such coloring agents should be water soluble and stable at 70C for several hours.

The gelatin solution does not have to be prepared under vacuum. No aging is required. A gelatin batch may be prepared in 2-3 hours by simple cooking in a jacketed melting vat with stirrer. The prepared gelatin may be poured directly into the machine's gelatin tanks, or may be cast and cooled into rectangular blocks for later use. For smaller operations such as in research environments, the gelatin can be prepared in the gelatin tanks within the GLOBEX MARK II encapsulator itself.

2. Formation, Filling, & Sealing of Soft Gels

Figure 1. on the following page schematically illustrates the soft gel formation process within the GLOBEX MARK II encapsulator.

Initially, a molten stream of gelatin is passed from either of the machine's two gelatin tanks at a constant rate through the outer of two concentric nozzles. The gelatin flows by gravity into the nozzle. In order to insure a steady flow of gelatin, the gelatin level in the tank and its temperature, 68C-70C (154F-158F), are maintained constant.

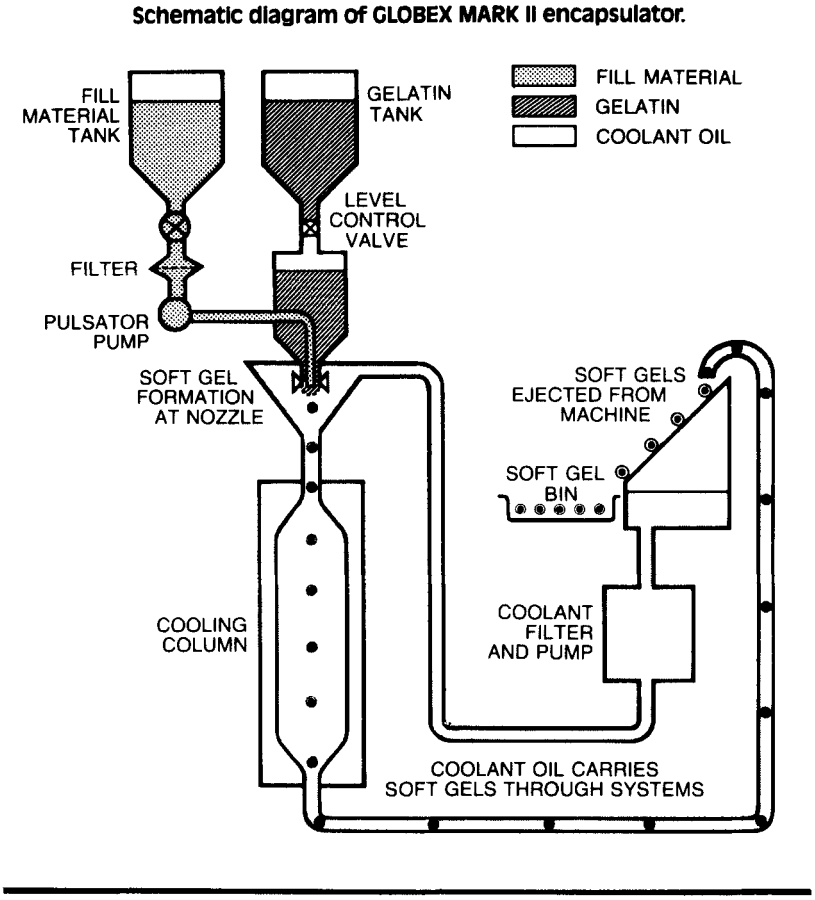

Figure 1. Schematic diagram of GLOBEX MARK II encapsulator

Simultaneously, the fill material is pumped from one of its tanks by means of a volumetric metering pump through the inner of the two concentric nozzles. The metering pump may be calibrated to any value of Specific Gravity between .9 and 1.2 insuring that the product fill weight will be accurate. The fill material is usually maintained at ambient temperature. However, for fill materials which are too viscous to flow well at room temperature, provisions for heating the fill material tanks and lines are provided.

Consequently, a concentric two-phase tubular-shaped liquid stream of molten gelatin and fill material is formed. As it emerges from the nozzle, the tubular stream passes into a coolant oil which is immiscible in the gelatin solution. The coolant oil is a light mineral oil, commonly known as Paraffin oil in Europe.

Immediately after the two-phase stream emerges from the nozzle and passes into the coolant oil, it encounters a second

stream of pulsating coolant oil. These pulsations constrict the continuous, two-phase, primary stream and cause it to break up into an intermittent, but steady flow of droplets. As the droplets are formed, the gelatin surrounds the fill material by natural surface tension. The physics of the phenomenon always produces soft gels which are spherical in shape and uniform in wall thickness.

The timed pulsations of coolant oil are caused by a mechanism within the metering pump. The pump and the pulsating mechanism are synchronized to each other in such a way as to assure that variations in pump speed will be compensated for by an equivalent adjustment in the pulse interval. This guarantees exact and equal doses of product in each soft gel.

The coolant oil carries the soft gels through a cooling column where they begin to congeal. In the process, the recirculating coolant oil is being constantly filtered and dried by an in-line Silica filter. The soft gels are carried through and ejected from the encapsulator into a receiving bin filled with cool mineral oil. Each bin holds approximately 10,000 soft gels. The mineral oil prevents the freshly formed soft gels from adhering to one another while protecting them from the atmosphere. This total immersion in mineral oil eliminates the need for air-conditioning in temperate climates. It also eliminates the risk of product contamination from airborne contaminants. A further unique feature of the machine is that all of the gelatin is consumed in the manufacturing process. There is no gelatin net formed, or any subsequent recovery equipment required.

Next, the bins are placed into a refrigerator, in order to enable the soft gels to congeal thoroughly.

3. Refrigeration

At this stage of their production, seamless soft gels have a relatively high water content, and are somewhat soft compared to rotary die produced soft gels. In order to enable them to better withstand the rigors of the cleaning process, seamless soft gels are refrigerated for at least 6-8 hrs. at 4C (38-39F). A standard single-door commercial refrigerator will hold 10 bins or 100,000 soft gels. These figures are based upon space requirements for 400 mg. size soft gels. (Approx. 7 minims @ .92 S.G.). For further reference, one minim of fill material with a specific gravity of .92 is equal to 56 mg.

4. Cleaning

After the soft gels have congealed thoroughly, they are separated from the coolant oil by a conventional sieve. In production quantities the soft gels are then placed into a centrifuge or a specially designed recirculating washer for complete cleaning and degreasing in a suitable solvent. Smaller quantities may be degreased by simply solvent rinsing within the sieve. Theoretically, any solvent which will dissolve the mineral oil without attacking the gelatin shell is suitable. In practice, however, regulatory agency restrictions as well as adherence to G.M.P. will reduce these to a few. Because local regulations vary, no specific recommendations are made here.

Next, the soft gels are spread onto specially designed, perforated drying trays. The trays are then stacked onto wagons and rolled into the drying chamber.

5. Drying

The drying of freshly made soft gels is an important factor in their production. In temperate climates, the drying of soft gels is not critical. A simple forced-air drying chamber will be efficient and economical. In more extreme climates, the conditions under which seamless soft gels are dried must be more carefully monitored and controlled. In these climates, a dryer which conditions the air is required. This special drying system allows all three parameters of temperature, relative humidity, and air flow to be carefully monitored and controlled with time. The drying process generally takes some 12 hours to complete. Slow drying of the seamless soft gels is recommended.

The completely congealed and dried soft gels are now collected into large bins from the drying trays, where they are sorted and inspected. Finally, samples are taken for necessary laboratory tests, and after approval, each batch is ready for packaging.

Refer to appendix "G" for an illustration of a typical plant layout.

PRODUCTION RATES AND SOFT GEL CHARACTERISTICS

Any size soft gel between 20 mg. and 750 mg. of fill material can be produced in 1 mg. increments by simply adjusting the rate of flow of product to the number of pulses per second of pulsating mechanism. Changing the flow rate of the fill material is accomplished simply by changing a gear ratio at the metering pump. The pulsation rate can also be changed quickly. Complete size changeover takes 5 to 15 minutes. Changes in specific gravity of the product are compensated for by simply changing the "specific gravity gear" on the pump.

By "miniaturizing" and "accelerating" the process, it is possible to produce mini-soft gels on the GLOBEX MARK II encapsulator. Dosage sizes range from 1 mg. to 20 mg. These applications, however, require modifications of the standard equipment.

In most instances, the smaller soft gels will contain about 50% gelatin while the largest soft gel will contain about 20% gelatin. Refer to Appendix "A" for a table showing % gelatin vs. size. The thickness of the gelatin shells range from approximately .10mm to .50mm (.004in.-.020in.). This thin shell is so strong that fully dried individual soft gels can withstand compression loads up to 50 kilos without rupture or leakage. The diametral size of seamless soft gels range from between 0.8mm-12mm (.030in.-.472in.). Both the ideal shell thickness and outside diameter will vary with the properties of the fill material. Refer to Appendices "B" and "C" for tables.

Soft gel weight refers to the net weight of the product within the soft gel and not to the total weight. Production rates of the GLOBEX MARK II encapsulator are dependent upon soft

Table 1. Production rates for the GLOBEX MARK II encapsulator

Soft Gel Weight	<--------Production Rates--------> per/min.	per/hour	per/day 2 (10 hr.) shifts
20 mg.	2240	134,400	2,688,000
50 mg.	1120	67,200	1,344,000
100 mg.	700	42,000	840,000
150 mg.	560	33,600	672,000
200 mg.	420	25,200	504,000
300 mg.	280	16,800	336,000
500 mg.	210	12,600	252,000
750 mg.	140	8,400	168,000

gel size and the nature of the fill material. Refer to Table 1. for estimated production rates.

PRODUCTION PROCEDURES AND STAFF REQUIREMENTS

One semi-skilled machine operator is needed to run three to five GLOBEX MARK II machines. Apart from the responsibility of setting up the machine for production in the morning, the operator's prime function is to make sure the GLOBEX MARK II machines are kept filled with gelatin and fill material. A time switch is built into each machine so that 2 1/2 hours before the soft gel production begins, all heating and cooling elements in the GLOBEX machine are automatically turned on. This allows the gelatin solution to be heated and the coolant oil to be cooled to the correct temperatures immediately before production begins. The operator must replace the soft gel bins every 30-60 minutes, depending on soft gel size, and place the filled bins in the refrigerator. The operator also insures that the temperatures of the gelatin (68C), coolant oil (3C-5C) and fill material (20C-22C) are constantly maintained. All process temperatures are thermostatically controlled and can be visually monitored from the front panel.

Simultaneously, at the beginning of the shift each day, a second semi-skilled worker empties the drying chamber of finished soft gels. They are placed into a large bin for sorting and inspection. He or she then begins to degrease the refrigerated soft gels from the previous days' production with a sieve and/or a centrifuge. The soft gels are washed in batches, spread onto specially designed drying trays and placed into the drying chamber. The other main responsibility of this worker is to prepare the gelatin solution in the cooker using the raw materials discussed earlier.

Only 5-15 minutes is necessary for soft gel size changeover. Complete changeover of size, fill material, and gelatin solution,

including clean-up, may take up to 45 minutes. If the same fill material is run on successive days, it is not necessary to clean the machine at the end of the days shift. All that is required is to shut the machine down. Production can resume the next day from materials stored in the encapsulator overnight. Both semi-skilled operators should assist in any changeover to insure the shortest make-ready time possible.

A technical skilled supervisor will be responsible for all formulations and production decisions. Assays will be regularly conducted to insure compliance with fill material dosage levels.

One worker can usually handle the sorting and inspection workload generated by the output of two machines.

PRODUCT APPLICATIONS

In general terms, The GLOBEX MARK II machine is suited to encapsulate oil soluble or lipophyllic substances in their liquid state. The fill material must be immiscible in water, due to the fact that the gelatin solution, at time of formation, is about 50% water. Light suspensions of solids in oils can also be encapsulated. The particle size of suspended solids should not exceed an average of 5 microns. It is even possible to mix slight amounts of water active ingredients in oils for seamless soft gel formation. Fill materials with a range of specific gravity between 0.8 and 1.2, and with viscosities of from 1.0 to 130 centipoise at 30C(86F) are ideal for seamless soft gel production.

Fill materials for soft gels in the food industry include flavor, spice and vegetable oils. Animal derived fats such as butter, chicken fat and lard can also be encapsulated. Citrus oils such as orange or lemon oil may be successfully encapsulated and packaged with other dry ingredients without interaction. For instance, seamless soft gels containing lemon oil can be packaged in a lemon meringue pie mix, keeping the oil fresh until time of use.

The health food industry has many applications for seamless soft gels. Fish oils, garlic oil, soya oil, wheat germ oil, and GLA are excellent candidates.

Fish oils are particularly interesting. Many people consume single doses of these substances as large as 1000 mg. which tend to dissolve completely within the stomach. Several, smaller sized, enteric coated, seamless soft gels offer a better "time-release" dosage form. Because of their perfectly spherical shape, and total absence of seams, seamless soft gels present few, if any, problems in enteric coating.

Vitamin manufacturers can produce seamless soft gels containing the popular and well known vitamins A, D, and E. Vitamin F (unsaturated fatty acids) and vitamin K (Acetomenaphthone) can also be produced in seamless soft gels. Mineral and multivitamin suspensions are also possible.

The GLOBEX MARK II machine can produce seamless soft gels with small dosages of oils, lubricants, and pesticides which are often called for in industrial or agricultural applications. For instance, strong insecticides could be encapsulated, sugar-coated, and sold as a poison which ants would carry back to their nests where it would have maximum effectiveness.

Applications in the pharmaceutical and medical industries include hormones, anti-angina drugs, chemotherapy dosages, anti-compulsives and anti-tussives. One example would be Valproic acid which is successfully being encapsulated as a seamless soft gel. Nifedipine is another. Successful initial trial encapsulations of certain Gattefosse excipients promise to further lengthen the list of process-compatible fill substances in the near future.

Cosmetics houses can encapsulate natural and synthetic perfume oils into seamless soft gel dosage forms. Bath oils are another interesting application in this industry.

Breath fresheners are a unique new seamless soft gel application. A significant market for this product has already developed in Japan. Chewing gums, breath mints, and breath sprays do not offer the convenience or potency of a 15 mg. seamless soft gel breath freshener.

COST ANALYSIS

The following cost analysis is based on the following assumptions:

(2) GLOBEX MARK II encapsulator

Size of soft gel: 240 mg.

Total Production rate for both machines:

50,400/hour
403,200/day (8 hours/day)
100,800,000/year (250 days/year)

Estimated costs for equipment and materials to produce soft gels on GLOBEX MARK II encapsulators are as follows:

Gelatin Preparation Equipment:

(1) Gelatin Kettle
(1) Batching Scale:100 kg.(220 lbs.)
(1) Water Demineralizer Unit
(1) Water Chiller Unit
(1) Viscometer
Misc. Pallet Racks
Rolling Wagons
Casting Trays
Total Gel Prep Equipment.....$40,000.00

Soft Gel Production Equipment:

(2) GLOBEX MARK II encapsulators.....$289,000.00*

50/500 gm. Dual range lab balance.....$1,500.00

* This includes freight, duty, insurance, and 2 week in-plant training.

Refrigeration Equipment:

(2) Refrigerator (300,000 soft gel capacity)
(10) Soft Gel bins
Total Refrigeration Equipment.....$9,000.00

Degreasing Equipment:

Soft Gel Washer (3 Basket)
Sieves
Total Degreasing Equipment.....$30.000.00

Drying Equipment: (Drying chamber for temperate climates only.)

Drying Chamber
(150) Drying Trays
(4) Wagons
Total Drying Equipment.....$25,000.00

Sorting Equipment:

(2) Sorting Tables.....$1000.00

Total Capital Equipment Costs:.....$401,500.00

Consumable Materials (per year):

		Annual consumption	Annual cost
Dry Gelatin	@$3.81/kg.	7104 kg.(15,630 lbs.)..	$27,066.00
Glycerine	@$1.87/kg.	2170 kg.(4776 lbs.).....	4,058.00
Water	@$ .13/liter	10280 liters(2706 gal.)...	1336.00
Coolant Oil	@$ .94/liter	2016 liters(530 gal.).....	1894.00
Degreasing	@$1.00/liter*	4032 liters(1060 gal.)...	4,032.00
	Total consumable materials cost.....		$38,386.00

Labor Hours:

(1) Semi-skilled operator for gelatin preparation, soft gel washing and drying: @$20.00/hour.....$40,000.00

(1) Semi-skilled machine operator for GLOBEX MARK II encapsulators: @$20.00/hour.....$40,000.00

(2) Sorter(inspector) and packer: @$10.00/hour.....$40,000.00

Total annual labor cost.....$ 120,000.00

* price dependent on specific degreasing solvent used.

Electric:**.....$5,000.00

Total costs: recurring.....$163,386.00

Encapsulation cost.....$1.64/M Soft Gels

Consumable Materials:(general information)

For amount of gelatin, glycerine, and water consumed in the GLOBEX MARK II machine, refer to appendices D, E, and F respectively.

Consumption of coolant oil and degreasing solvent are independent of soft gel size. Twenty liters(5.3 gal.) of coolant oil and 40 liters (10.6 gal.) of degreasing solvent are consumed in the production of 1 million soft gels. If a fill material changeover occurs, all the coolant oil in circulation, 35 liters (9.2 gal.), should be replaced. If no fill material change occurs the same coolant oil can be used for the entire run of product. Changeover costs are not taken into consideration for the cost analysis. Paraben consumption is dependent on the desired formulation and will be assumed negligible compared to other major material costs.

Space Requirements:

One GLOBEX machine occupies .864 sq. meters(9.6 sq. ft.) of floor space. It's height is 2.67 meters(8.9 ft.). A complete two machine plant requires no more than 135 sq. meters(1500 sq. ft.) of space. Refer to appendix "G" for typical two machine plant.

PROCESS LIMITATIONS

Limitations to the production of soft gels by this process fall into four broad categories. All are directly attributable to the physics of the dieless, "drop formation" process.

They are:

1. Limitations of shape.
2. Limitations of size.
3. Limitations of fill material.
4. Limitations of speed.

1. Limitations of shape.

Because they are freely formed, all seamless soft gels are necessarily spherical in shape. Slightly oval shapes can sometimes be produced by freely linking two consecutive, still molten droplets immediately after formation. However, these are not true ovals such as would be produced on rotary die equipment.

** GLOBEX MARK II encapsulators operate at an average power of 1.7 KW. Provisions in wiring should be made for momentary power levels of 4.0 KW. Standard voltage in the U.S. is 220 volt/60 Hz./1 phase, with earth ground.

2. Limitations of size.

Freely formed soft gels are limited in size, although this limitation is more restrictive at the high end of the size range. Just as soap bubbles freely floating in air become more unstable the larger they become, so do freely formed soft gels. Small soft gels are better suited to the process. Reiterating what was said earlier, a range of sizes between approximately 1 and 12 millimeters in diameter is practical. This correlates to a range of fill weights of between 10 and 750 mg.

3. Limitations of fill material.

Not all fill materials are suitable for encapsulation by this process. Generally speaking, the process limits the fill materials to hydrophobic liquids with specific gravities of between .9 and 1.2, and viscosities of between 1 and 130 centipoise at 30C. It is not possible to encapsulate aqueous or hydrophyllic liquids of any kind such as alcohols, glycerides esters, detergents, surfactants, or emulsifiers. Generally speaking, most hydrophyllic liquids are difficult to encapsulate, unless suspended in an oil soluble product, and then only in small quantities

4. Limitations of speed.

The GLOBEX MARK II encapsulator produces soft gels one at a time. Therefore, it's output rate is slow when compared to that of a large production type rotary die machines. This is not a fair comparison, however.

In fact, a single GLOBEX MARK II encapsulator can produce a substantial number of soft gels in a day's time. Furthermore, the process is so reliable that there is little or no downtime expected. Once production is started, there is almost an uninterrupted flow of soft gels. Theoretical and actual production rates are very close.

In addition, the price of a single GLOBEX MARK II encapsulator is many times less than that of a large rotary die machine and encapsulation costs are very attractive. Therefore, the economics of a plant producing seamless soft gels on multiple machines compares favorably to that of a rotary die plant.

Furthermore, a multiple machine plant eliminates the possibility of complete non-productive downtime. It also allows the flexibility of simultaneous production of multiple products or parallel production of the same product as the requirements dictate.

CONCLUSION

Seamless soft gels have a definite place in today's market alongside soft gels produced on standard rotary die machines. Because of size, shape, and fill material limitations, however, the production of seamless soft gels by this method will never replace that of rotary-die produced soft gels. Nevertheless, despite the limitations, in certain applications seamless soft gels offer the best choice among all other alternatives including seamed rotary die produced soft gels.

Finally, self-manufacturing soft gels on GLOBEX MARK II encapsulators offers a viable and economical alternative to outside contract manufacturing of these types of products. Bringing the research, production and quality assurance aspects of producing soft gels under the roofs of non-traditional manufacturers, creates an opportunity never before available for researchers and marketing people to seriously consider soft gels at the very first stages of every new product development.

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APPENDIX A

SOFT GEL SIZE (mg.)	% GELATIN
1	50.0%
10	46.0%
20	43.0%
50	38.5%
100	35.0%
110	34.5%
150	32.8%
160	32.6%
165	32.5%
200	30.8%
225	30.0%
250	29.5%
275	28.8%
300	28.0%
350	27.0%

400.....26.0%

450.....25.0%

500.....24.0%

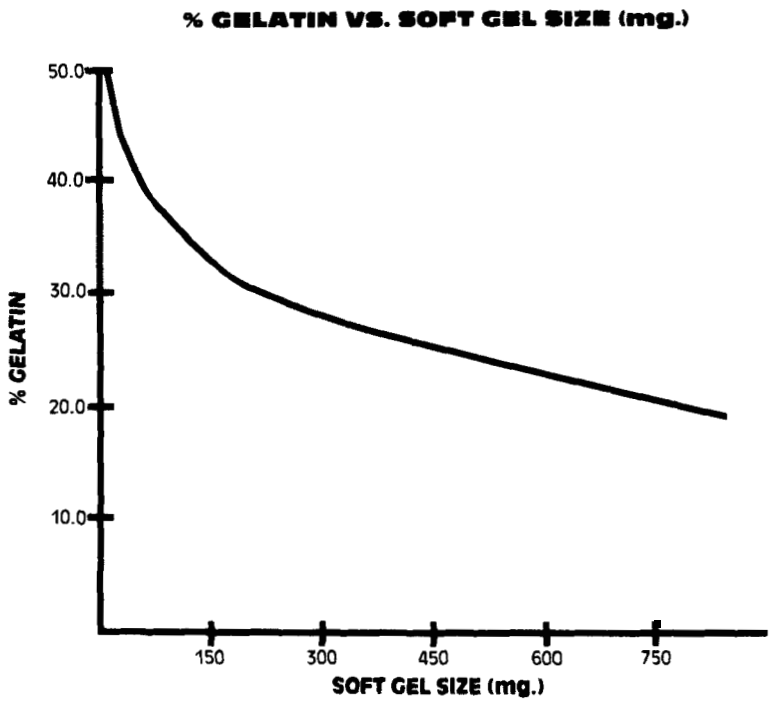
550.....23.0%

600.....22.4%

650.....21.5%

700.....20.8%

750.....20.0%



Appendix Figure A. Percent gelatin vs. soft gel size.

APPENDIX B

SOFT GEL SIZE (mg.)	SOFT GEL DIAMETER (mm.)	(INCHES)
1	0.8	.031
10	2.8	.110
20	3.7	.146
50	5.0	.197
100	6.4	.252
110	6.6	.259
150	7.3	.287
160	7.5	.295
165	7.6	.299
200	8.0	.314
225	8.3	.327
250	8.6	.338
275	8.8	.346
300	9.0	.354
350	9.3	.366
400	9.6	.378
450	10.0	.393
500	10.3	.406
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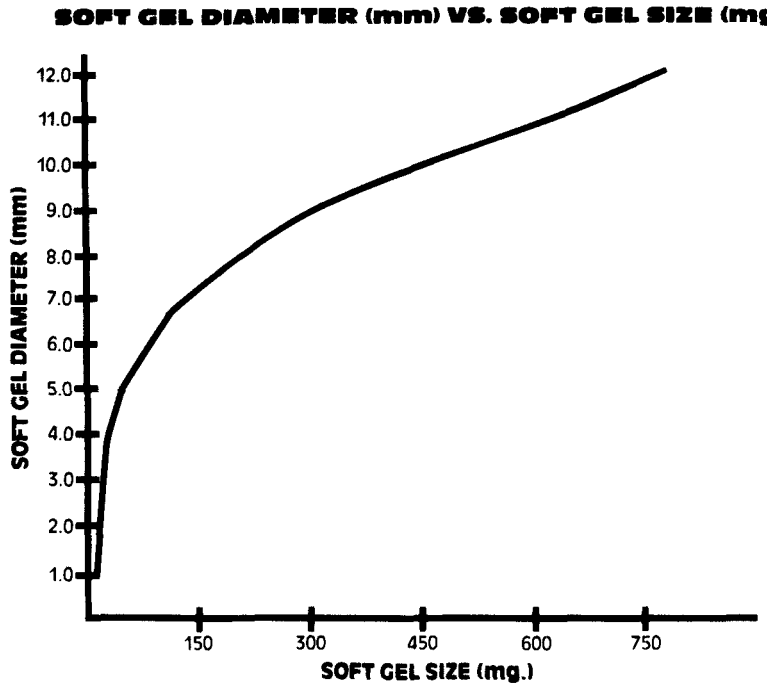
600	11.0	.433
650	11.3	.445
700	11.6	.457
750	12.0	.472

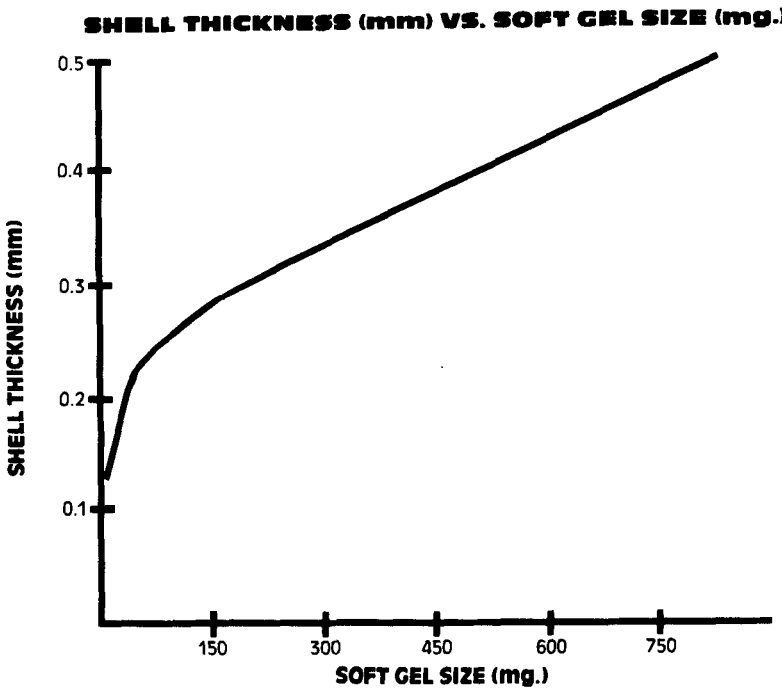


Appendix Figure B. Soft gel diameter vs. soft gel size.

APPENDIX C

SOFT GEL SIZE (mg.)	SHELL THICKNESS (mm.)	(INCHES)
1	.150	.0059
10	.180	.0071
20	.210	.0083
50	.242	.0094
100	.260	.0102
110	.270	.0104
150	.280	.0110
160	.282	.0111
165	.284	.0112
200	.294	.0116
225	.310	.0122
250	.315	.0124

275	.320	.0126
300	.330	.0130
350	.347	.0138
400	.364	.0144
450	.380	.0149
500	.400	.0157
550	.412	.0161
600	.430	.0169
650	.441	.0173
700	.457	.0181
750	.470	.0183

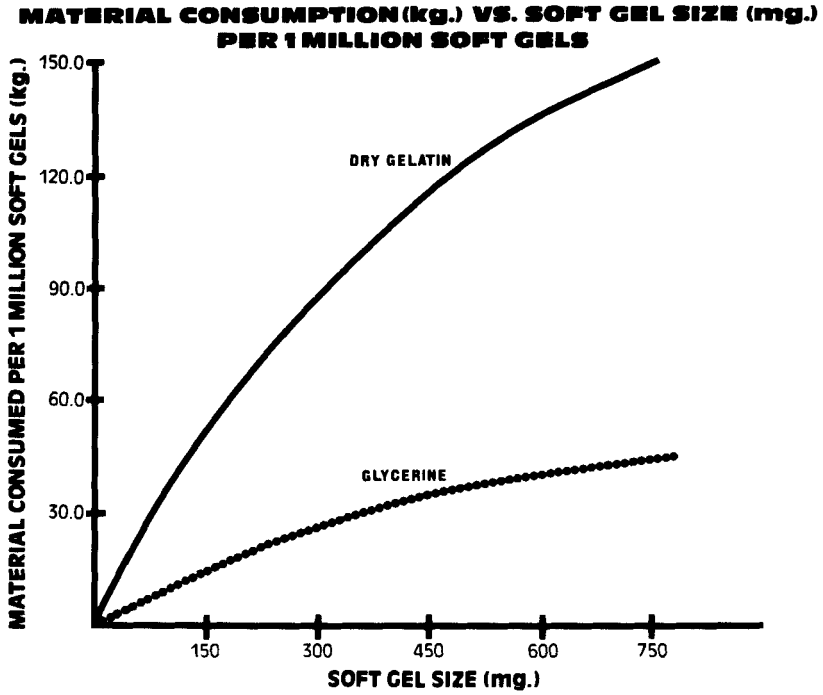


Appendix Figure C. Shell thickness vs. soft gel size.

APPENDIX D- DRY GELATIN*

SOFT GEL SIZE (mg.)	WEIGHT (kg)	WEIGHT (lb)
1	0.47	1.04
10	4.46	9.83
20	8.55	18.85
50	19.48	42.95
100	36.10	79.59
110	40.05	88.29
150	49.85	109.90
160	50.00	110.20
165	54.02	119.12
200	62.75	138.31
225	68.43	150.92
250	73.60	162.30
275	80.00	176.40
300	85.54	188.68
350	96.42	212.62
400	106.43	234.64
450	115.43	254.54
500	123.52	272.34
550	130.85	288.57
600	136.88	301.83
650	142.07	313.25
700	146.34	322.65
750	149.66	329.94

* per 1 million soft gels



Appendix Figure D. Material consumption vs. soft gel size per 1 million soft gels.

APPENDIX E- GLYCERINE*

SOFT GEL SIZE (mg)	WEIGHT (kg)	WEIGHT (lb)
1	0.14	0.31
10	1.32	2.91
20	2.90	6.39
50	5.81	12.81
100	10.83	23.88
110	12.00	26.46
150	14.94	32.94
160	15.07	33.22
165	16.28	35.89
200	18.81	41.47
225	20.52	45.24
250	23.08	50.88
275	24.01	52.93
300	25.69	56.64

* per 1 million soft gels

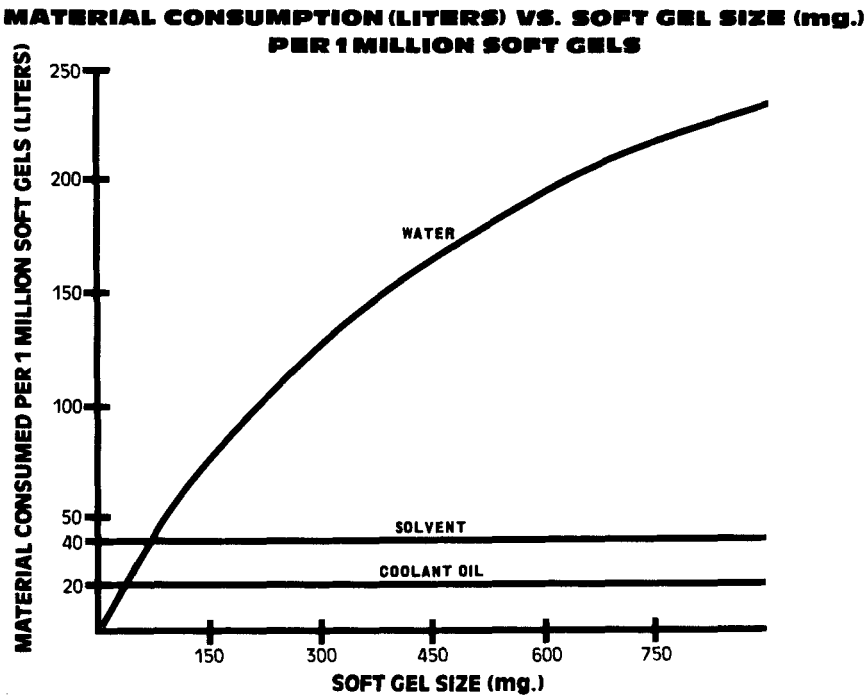
350	28.90	63.72
400	31.96	70.46
450	34.62	76.32
500	37.10	81.79
550	39.30	86.64
600	41.10	90.61
650	42.65	94.03
700	43.90	96.78
750	44.94	99.07

APPENDIX F- WATER*

SOFT GEL SIZE(mg.)	AMOUNT(liters)	AMOUNT(gal.)
1	0.69	0.18
10	6.44	1.69
20	12.35	3.25
50	28.14	7.40
100	52.13	13.72
110	57.78	15.20
150	71.93	18.93
160	72.22	19.00
165	77.99	20.53
200	90.57	23.83
225	98.79	25.99
250	106.31	27.97
275	115.55	30.41
300	123.49	32.49
350	139.24	36.64
400	153.68	40.44
450	166.68	43.86
500	178.39	46.94

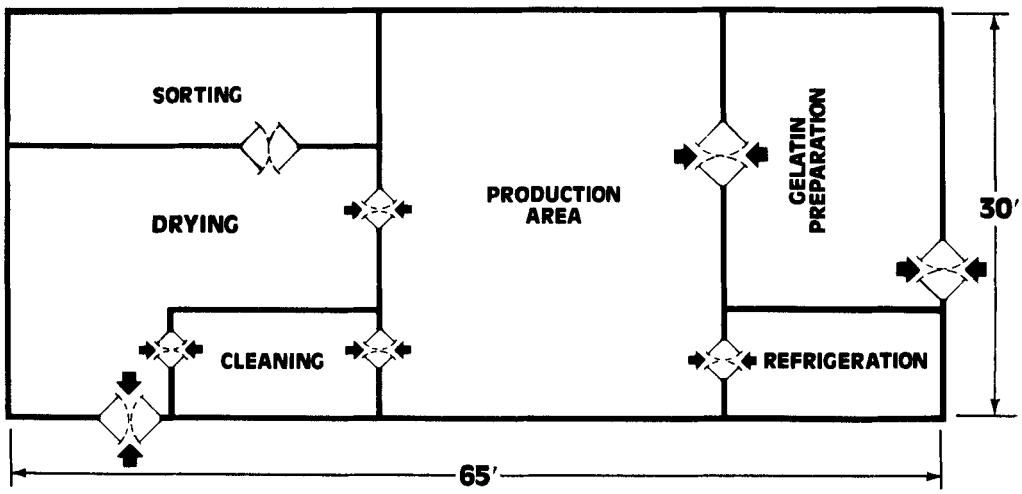
* per 1 million soft gels

550	188.93	49.72
600	197.59	51.99
650	205.05	53.96
700	211.32	55.61
750	216.08	56.86



Appendix Figure F. Material consumption vs. soft gel size per 1 million soft gels.

APPENDIX G- PLANT LAYOUT



Appendix Figure G. Plant layout.