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A second line of powder fillers is the CMR series: a series of higher speed rotary machines capable of virtually dust-free operation at up to 450 cpm. Most of these fillers incorporate the Perry Accofil system for greater filling accuracy. The machines are produced by Perry Industries, Inc.

In a few instances powders must be filled into non-metallic containers, and here static charges can be a serious impediment to obtaining a clean, accurate fill. Herbert Products, Inc., the 3M Company and other firms have deionizing equipment that can effectively eliminate this difficulty.

Liquid Concentrate Fillers

The selection of the concentrate filler may involve one of the most difficult and cost-intensive decisions a packager must make during equipment selection. A series of compromises must be made in relation to price, job requirements, maintenance and other factors. Some of the general types are:

a. Vacuum or vacuum-gravity — constant level — liquid.
b. Piston — volumetric — liquid, semi-viscous.
c. Pressure-time — liquid, semi-viscous.
d. Pocket filler — volumetric gravity — liquid.
e. Time-gravity — liquid.

The first consideration is the type of concentrates which must be handled. For the contract filler this will normally mean a wide variety of liquids, ranging from low viscosity to barely pourable types. Filling weights may vary between 6 and 600 grams, and this particular variation is generally best handled by the use of change-parts; e.g. different orifices or different cylinder sizes. The captive filler may use his machine for the filling of only one or two products, in which case the buying decision is much easier.

Other considerations may be summarized as follows:

a. Time required for mechanical changeover from one can diameter to another or from one height to another.
b. Cleanability of the machine. Time required to break down and thoroughly clean all contact parts such as filler bowl, filling nozzles, pistons, cylinders, valves and so forth.
c. Maintenance accessibility. Access to the motor, gear reducer and drive train is very important in case of breakdown as well as for regular maintenance.
d. Maintenance level. Consider the degree of protection given to the motor, power train and other moving parts so that concentrate spills and flush liquids will not come into contact with them and reduce their operational life. Maintenance often increases as the number of elastomeric seals increases. The seals must be made of materials compatible with the concentrates.
e. Ability of the machine to function reliably without the need for a machine operator. This saves on labor but may increase maintenance requirements.
f. Cost. A good high speed filler will cost from $20,000 to $80,000 if purchased new. A used filler has a much lower initial cost, but maintenance costs will be much higher, and production losses due to breakdowns more frequent. Older machines tend to leak and have less accuracy.

A very large number of equipment manufacturers offer concentrate fillers. Each has unique advantages and disadvantages. It has been said that the experienced maintenance man or filler operator can detect a "personality" in every filler, and that even supposedly identical fillers will respond quite differently to various production situations. By developing a rapport with filler idiosyncrasies the maintenance man can predict problems, lay in stores of change parts known to have short service lives, and make adjustments that will enable the machine to give maximum performance.

Typical fillers are listed as follows:

a. The "JG Volumetric Product Filler" (also designated as the "Model VOF-A Automatic Volumetric Filler" when mounted with conveyor system) is available from the JG Machine Works, Inc. (Patterson, NJ) The Model VOF-A has a reported accuracy of $\pm 0.25\%$ which makes it very interesting. Interchangeable product fill cylinders are available in 30 to 550 cc. capacities. The Model VOF-A provides speeds up to 65 cpm. depending on fill and viscosity.
b. "Cozzoli Filler", by the Cozzoli Machine Company (Plainfield, NJ) The 8-head model does about 50,000 units per shift under average fill conditions and the 16-head can do almost 100,000 units per shift on a similar basis. Highly versatile,

with product cylinders from 20 cc. to 600 cc. The 20 cc. size provides tolerances of better than ±0.1 gram, even with slurries.

The 16-head can also fill two concentrates, one in each 8-head in-line section, or the same concentrate twice, if an especially large volume fill is needed. Filler speeds are decreased to about 50% under these conditions.

c. The Filler Machine Co. (Philadelphia, PA) supplies versatile piston fillers in rotary, multi-in-line and single in-line models. Their 8-head rotary operates from 120 to 200 cpm, depending upon fill conditions.

d. The National Instrument Company (Baltimore, MD) manufactures a large line of "Filamatic" in-line and rotary piston fillers which are versatile, very accurate and fairly inexpensive. While many models have limited speeds, the larger in-lines and their Model 400R 16-station rotary can handle the needs of any high speed aerosol filling operation.

A wide variety of accessories are available, such as pumping units to push high viscosity products fully into the piston filling cylinders, final filters that locate between the discharge valve and filling nozzle to "polish" concentrates immediately prior to filling, and heaters for handling gel-type and similar products that must be filled in the 150°-200°F (66°-93°C) range.

e. The U.S. Bottlers Machinery Co. produces a line of rotary vacuum fillers which are excellent for water-based aerosol concentrates. The 36 head unit will handle the largest aerosol fills at speeds of 280 cpm.

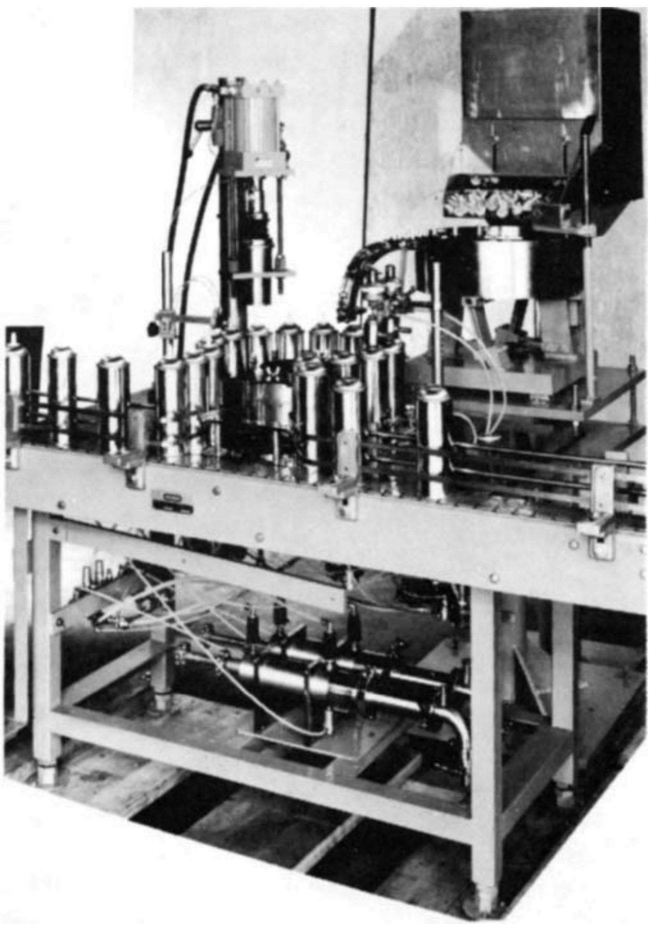
f. "Levelmatic Filler", by the New Jersey Machine Co. High speed, uses a unique fluidic sensor to control liquid level in the can, eliminating need for an overflow system and speeding up cleanup and changeovers.

g. The New Way Packaging Machinery Inc. firm (Hanover, PA) produces an extensive line of product fillers and accessories. Their Model 700 Automatic Rotary Liquid Filler can be used for filling medium to larger size aerosols, and actually other containers up to about one-gallon (3.785 liters) in size for "duplex" (aerosol and non-aerosol) production line requirements. The 24-head filler can run to 200 cpm in the case of foaming or non-foaming products and will fill fairly viscous items, but more slowly.

A smaller product filler, the 12-head Model A31, will do up to 72 cpm with fills ranging from 10 g to several liters.

h. In England a number of advanced-design fillers are available from such firms as the Neumo Division, P&L Industries Ltd. (England); C.E. King, their "Technfill" machines with a dial-a-dose volumetric control to below ±0.5%, starting at 1 ml fills; DH Industries Ltd., where mini-fillers are available to handle inhaler aerosol slurries, for instance, and use a recirculating system with an air-operated filling nozzle on the end of a slave cylinder; and Adelphi Manufacturing Ltd., whose new Mark V Accramatic electronic filler will handle from 1 to 700 ml fills at low to

Figure 18. Food Aerosol Machine
Nalbach Model 16-RS



moderate speeds. A single length of tubing acts to both draw and dispense liquids.

Additional firms that supply product fillers include:

a. The Kartridg Pak Co. (Model 124 rotary, 24 head, ±0.5 ml.)
b. Cherry-Burrell Corp.
c. MRM/Elgin Packaging Machinery Corp.
d. Terco Inc.
e. Pneumatic Scale Corp., Ltd.
f. Pacific Packaging Machinery Co.
g. John R. Nalbach Engineering Co., Inc.
h. Hercules Inc.

Several of these firms provide integrated fillers and crimpers, or filler/crimpers/gassers. The Nalbach Model 16-RS Food Aerosol Machine, illustrated in Figure 18, includes twin sanitary product fillers, automatic valve sorting, a valve crimper and coder in one compact unit. It will handle about 30 cpm, or 25,000 units per day on a two shift basis.

In the Terco Indexing Rotary Filling Machine, rated at 100 cpm and illustrated in Figure 19, the product fillers are only one small component of the overall integrated assembly. Such lines often contain propellent charging equipment. In this case close-coupling of the gassers may fail to consider the need for separate gas houses for hydrocarbon injection. The Terco Inc. 40 cpm rotary equipment shown in Figure 20 is completely air operated and, for hydrocarbon gassing operations, is designed to be located in a gas house. All stations are interlocked, so that the slowest controls the line speed. It also has a no-container no fill-feature. Situated around the three foot (914 mm) plastic disc are a can cleaner, coder, twin fillers, a purger, crimper and two propellent chargers.

Various accessories are often added to concentrate fillers, some more necessary than others. For example, one company has developed various types of continuous sonic defoaming systems for reducing problems often encountered with rug cleaner concentrates, bathroom cleaner concentrates and other high-foaming liquids. The Herman H. Sticht Co. (New York) has their Standco Model 450 and other dial gauges for continuously monitoring the production rate of fillers as a function of the revolutionary speed and number of heads. Some fillers have built-in screens or filtration systems, but in most cases a final filter is placed on the

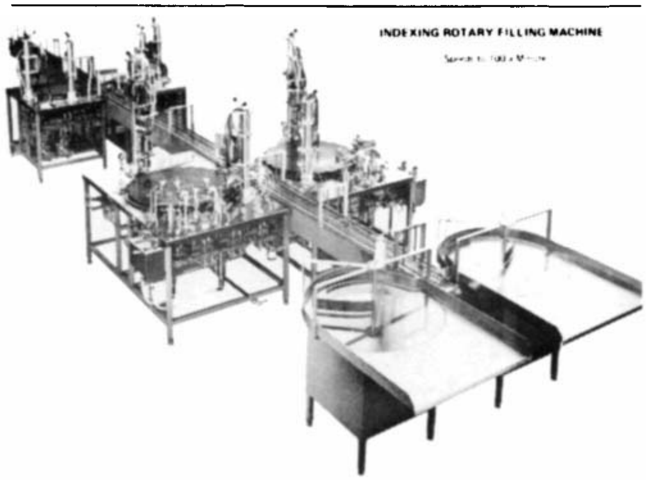


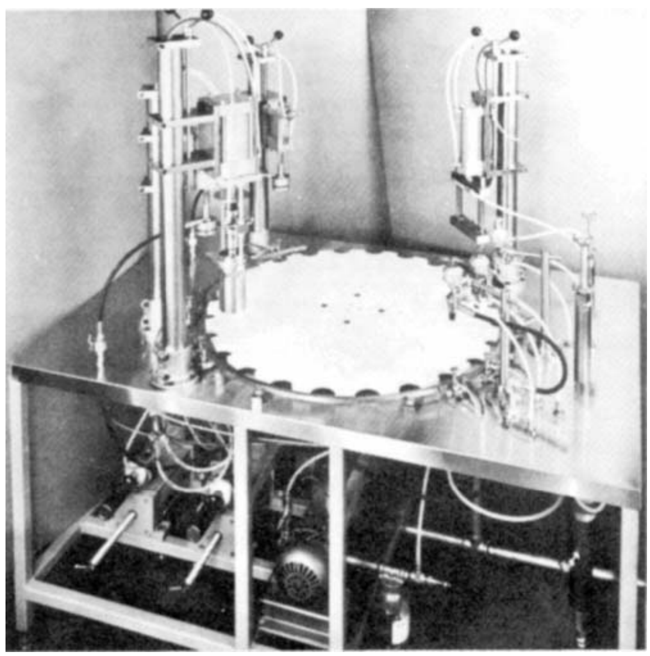
Figure 19. Rotary Filling Machine 100 CPM
Indexing rotary filling machine by Terco, Inc.

incoming product line, just before the filler.

The larger fillers are very complex machines, with over a thousand individual parts, and it is necessary to maintain a suitable supply of replacement items: springs, gaskets, adapters, sealing rings and so forth. It is a good idea to permanently number the individual filling heads of both in-line and rotary fillers, using solvent-resistant colored tape made for such purposes.

The filling of glass aerosols requires specialized equipment, as illustrated in Figure 21. Here a Nalbach

Figure 20. Rotary Filling Machine 40 CPM
Unit with cleaner, coder, fillers, purger, crimper and gassers. Made by Terco, Inc.



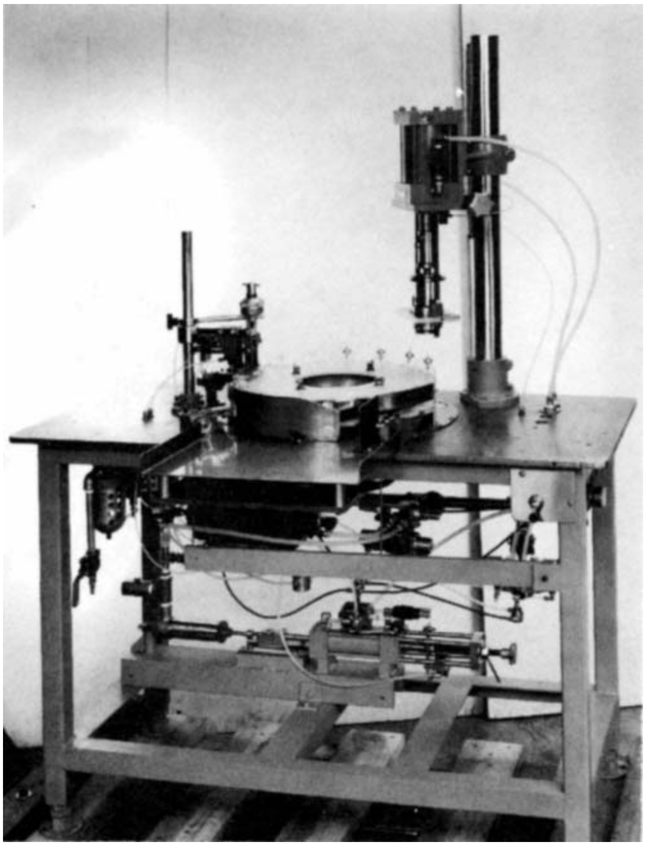
Glass Aerosol Filler and Crimper is used for the slow-speed rotary filling of various glass, plastic-coated glass and 20 mm type aluminum tubes (in pucks, if they are very slim), with either hand or.conveyorized container entry.

Checkweighers

These small machines became important during the early 1960s as a permanent quality control feature of larger aerosol lines. A typical unit is the "Metramatic" Model 121806, by the Metramatic Corp. Most high-speed lines have one of these checkers, usually situated right after the gassers and often in the gassing house. But some also have a checker located after the filler as well. It basically comes down to a matter of dedication to quality and available funds.

Because the checkweighers can only determine the gross weight, and since the weight of the empty metal cans will often vary up to about ±8% (generally within ±5 g, however) the checkweigher readings will not replace production control and quality control weight validation routines. The checkweigher may be set to reject units weighing outside ±6 g of the target weight, since on the basis of taking the square root of the sum of the square of can variation and the square of fill variation, this would allow for a can variance of ±5 g and a fill variation of ±3.3 g. Cans rejected by the air blast or air-operated ram at the end of the checkweigher move into a small collection area and are normally rechecked by hand on a small balance. Overweight cans are often sprayed down to the desired range. Underweight cans may be "short-shotted" with a few grams of additional propellent. Both practices are being increasingly frowned upon by highly quality conscious marketers, however, and may be used to a lesser extent in the future than now. The prevailing opinion is that an off-weight can is out of specification because of under- or over-filling of either the concentrate or the propellent; not both. The balance between the two is therefore upset and the can does not contain the stipulated percentages of each. The "whitewashing" type corrections just mentioned do nothing to rectify the underlying problem, except fortuitously in the case of short-shotting.

Figure 21. Tube and Glass Aerosol Filler and Crimper by John R. Nalbach Engineering Company



Checkweighers are readily available that are rated for 200 to 300 cpm. When one is used at speeds faster than the nameplate rating it will tend to kick out more correct weight cans than the normal 0.1% or so. Checkweighers for very small aerosols often have lower speed ratings of 40 to 80 cpm. Microprocessor controls automatically compute various statistics.

Valve Inserters

Both in-line and rotary models of these large machines are available from a number of suppliers. When purchasing one of them certain considerations should be given to attributes such as:

a. Changeover time, for the range of cans to be run on that line.

b. Change parts which will be needed.

c. Delivery schedules — sometimes very long.

d. Maintenance accessibility

e. Can handling capabilities.

The sorting abilities of most valve inserters are about the same. Special problems may arise when attempting to sort aluminum valves, stainless steel valves, valves without diptubes or valves with extra-large diameter diptubes. In some instances, a so-called "dummy diptube" can be applied to valves designed for inverted actuation, thus facilitating can handling. Various sensing devices improve quality control aspects of this operation. For instance, a mechanism using either a micro switch or electric eye may be used to reject valves with no diptubes as they pass along the slot conveyor toward the inserter station.

Valve inserters are quite large. The PMC Industries, Inc. Model VP2 and CR-1200 inserters consist of a valve bin, a separate sorter connected to the bin by means of a magnetic escalator belt, and the rotary inserter unit, connected to the sorter by the slot conveyor. The units may be arranged linearly or in an angular fashion, depending on space allocations. The linear length can easily exceed 18 feet. If all units are floor-mounted, the ceiling height should be 10 feet or more, but it has now become fashionable to place the sorter and bin sections on a mezzanine and lead the slot conveyor to the inserter through a rectangular hole in the deck. This arrangement is desirable in that it also provides for valve storage, case knockdown and stacking, and generally affords better raw material access than is available through the congested production area. Perhaps the smallest inserter is Nalbach's Model VS Sorter plus Model VP Inserter, capable of 35 cpm. The in-line Kartridg Pak machine operates between 50 and 360 cpm and costs about $60,000. It is illustrated in Figure 22.

Inserter mechanisms may differ in small but significant ways. When the Precision Valve Corp. PE-sleeve innovation was first production-tested in the U.S.A. at the end of 1981 it was found that the PMC inserter would not work with the new, smaller mounting cup, without one very minor change. The inside wall diameter of the four available PE-sleeve cup variables is 0.944" ± 0.003" (24.00 ± 0.07 mm) instead of the usual 0.969" ± 0.003" (24.61 ± 0.07 mm) — like the PVC nylon (Zytel 101) clad valve cups which are 0.963" ± 0.003" (23.80 ± 0.07 mm). In the PMC inserter a double-split nylon tube is used to spring-fit very snugly into the mounting cup, so that the valve can be lifted and then inserted into a waiting aerosol can. The tube has a diameter of about 0.980" ± 0.002" (24.89 ± 0.05 mm) and it could not bend inward sufficiently to fit within the smaller PE-sleeve valve cups. By making four additional slits in the tube (or a total of eight) a workable tube is possible, but a better method is simply to machine an existing one to about 0.955" ± 0.002" (24.26 ± 0.05 mm) and use it only for PE-sleeve or nylon clad PVC valve cups.

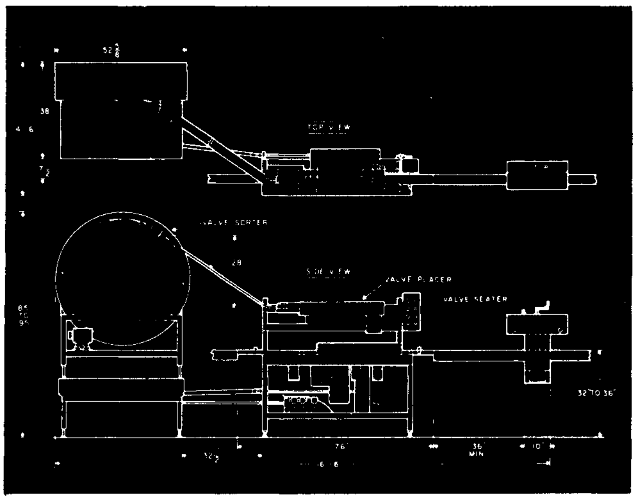
Valve Crimper

In the case of one-inch (25.4 mm) cans the valve crimper may be a separate in-line or rotary machine, a functional station in an in-line or rotary device that performs several operations, or a functional phase in a complex machine such as a Kartridg Pak U-t-C gasser. Where 13 mm or 20 mm ferrules are involved, the operation is done either separately or as one operation of an in-line or rotary multiplex device, such as that illustrated in Figure 21.

Although the area of terminology is somewhat blurred by misuse, "crimping" is normally thought of as the outward spreading of collet segments or jaws to make an hermetic seal. The operation is commonly called "swaging" in the United Kingdom. On the other hand, "clinching" is a term reserved for the inward compression of valve ferrules by means of collet tines, to make an air-tight seal. "Roller-clinching" has been used to describe a process where several flat wheels converge inwardly on a ferrule or (less commonly) a one-inch (25.4 mm) valve cup to seal them on various containers. In the new PET (polyethylene terphthalate) plastic bottles, developed in Europe in 1980, and currently under development in much larger sizes in the U.S.A., it appears that roller-clinching is the preferred method of closure. Before this the only time one-inch (25.4 mm) valve cups were clinched or roller-clinched was in the case of the old Risdon Model JBR "turret-type" valve of the 1950s.

Valves may be either atmospherically crimped or vacuum crimped. Vacuum crimpers of both in-line and

Figure 22. Automatic Valve Sorter and Inserter by The Kartridg Pak Co.



rotary formats were introduced about 1957, but they did not become popular until the 1960s. At that time many CFC type products were cold-filled and propellent vaporization very effectively removed the tramp air from the head space. For pressure loaded products air could be removed by means of CFC gas jets and drips, or by means of CO_2 gas streams. (CO_2 was then priced at only about $0.03/lb. ($0.066/kg) in bulk, at least in many parts of the country.)

The early rotary vacuum crimpers were able to draw up to a 25" Hg° (-84.7 kPa) vacuum in cans having head spaces of about 150 ml or less, which is about 83.6% of a full vacuum and rather phenominal by today's standards that normally range from about 16 to 21" (-54.2 to -70.9 kPa) for K-P Under-the-Cap machines and other composite equipment. Drawing partial vacuums on cans is somewhat useful in minimizing full-can pressures and in slowing the effects of some forms of corrosion, but in general the advantages of vacuum crimping are overstated.

A single-head one-inch (25.4 mm) valve crimper is nominally rated at about 60 cpm, but they have been driven to 75 or 80 cpm on some lines by the application of modest engineering changes. When these same heads are used for vacuum crimping, the rate often falls as the evacuation level increases. An indication of the amount of air withdrawal necessary to achieve certain vacuum levels is shown in Figure 23.

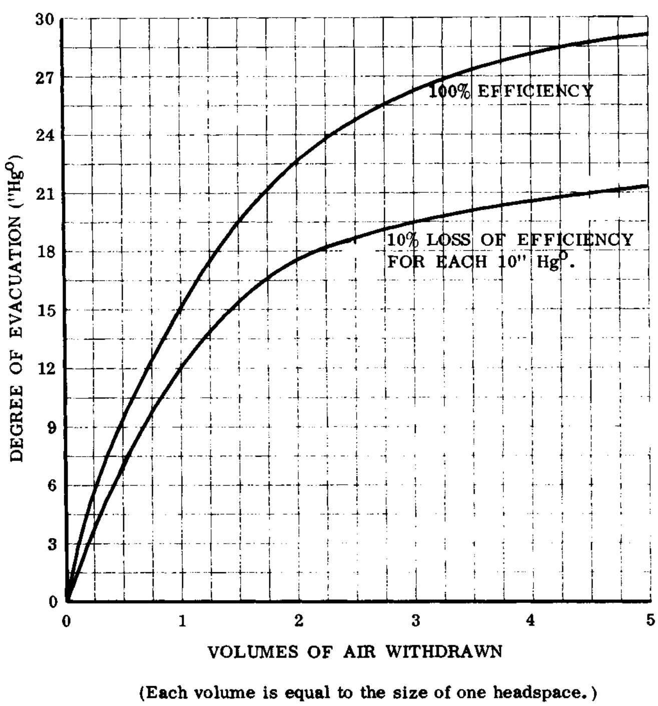


Figure 23. Theoretical and Typical Can Evacuations

The single-head units made by Nalbach, such as Models 1-HVC and 1-HCRP, can use either the outward crimping collet for one-inch (25.4 mm) valves or the inward clinching collet for ferrule type closures. Large machines are available from this supplier. Their Model 4-HVC consists of four heads in a rotary frame and can handle from 50 to 150 cpm, depending upon head space size and the degree of can evacuation reqired. A still larger unit with eight heads runs at rates of 80 to 240 cpm on the same basis.

The J.G. Machine Works, Inc. produces a line of quality standard, vacuum and ferrule type crimpers of the one-head design, rated at up to 60 cpm. Crimpers are also sold by The Kartridg-Pak Co., Terco Inc. and other suppliers.

Ferrule crimping is done by changing over standard crimpers with standard change parts, or by using regular ferrule clinchers. Clinching is often considered to be a more demanding operation than crimping, since there are several bottle finish diameters (and thus ferrule diameters) and several depths according to the container profiles. Different settings are required for plain glass, plastic coated glass, various types of aluminum tubes and straight plastic aerosol containers. At least five top finish designs are used for aluminum tubes.

As an added complexity, the Rudy Lechner barrier pressure packs (distributed by On-Line Equipment subsidiary of John Lelliot Ltd. in the U.K., Ireland and the Middle East, and by Aerosol Services, A.G., Switzerland, in the rest of the free world) use an internal aluminum tube or pouch with a flange and thin cut gasket that fits between the monobloc aluminum can curl and the valve. The ferrule clinching height must be adjusted downward to allow for the inserted flange and gasket. The Lechner system is also available for one-inch (25.4 mm) cans, and the same considerations apply.

A bottle crimping collet is much larger than the collet for cans having a one-inch (25.4 mm) plug, and several times more expensive. The adjustment of clinching depth is made by adding or removing shims from under the valve sealer. The shims are generally from 0.005" to 0.010" (0.127 to 0.254 mm) thick and are made of hardened steel. The distance between the valve sealer and collet jaws governs the tightness of the clinch. For a plain glass bottle with a typical 0.209" ferrule skirt, the distance from the bottom of the valve sealer to the bottom of the collet is about 0.235" (5.97 mm). The same setting is used for plastic coated glass containers, where the skirt length may extend to 0.335" (8.51 mm) in order to bind the plastic to the glass more effectively.

The Kartridg Pak Co. supply their Model 919 for slower speed operations, plus a variety of machines for speeds running to 120 cpm, and even higher. Similar equipment is available from several other suppliers.

Propellent Gassers

Pressure chargers can be classified into two main categories: those that fill through the crimped or clinched on valve and those that fill around crimped on valves. The first is sometimes called a T-t-V (Through-the-Valve) type and includes both the liquid injection machines and the gasser-shaker for gaseous gases. The second is generally called the U-t-C (Under-the-Cap), from terminology suggested by the supplier: The Kartridg Pak Co., who like to call a cup a cap.

T-t-V liquid injection chargers act to force liquefied propellents through the valve under pressures that are typically in the range of 650 to 1,100 psig (4.48 to 7.58 MPa) but most often in the middle half of that pressure span. The injection pressures are derived either from an air-powered booster cylinder assembly or liquistatically operated booster pumps, such as Union or Wheatley types. A very large number of valves are designed specially to accept propellent at rates of 300 ml/sec. They are called pressure filling or PF valves. One very effective design by Precision Valve Corp. is known as the "splined cup and hex-gasket" valve. The availability of all these valves has rather effectively reduced the gassing speed barrier that used to be a fair-sized problem for the T-t-V fillers.

A very low speed, very simplistic filling, crimping and gassing operation is shown in Figure 24. Even on this small scale it would be considered inappropriate to gas products within anything other than a separated explosion-proof structure with high ventilation, propellent sensing and all the other features that make up what is commonly called a gas house.

For any installation much larger than this, the propellent must logically be transported to the filling location in either tank cars or tank trucks and be stored in above-ground bulk tanks. Many of the larger fillers have one or two dozen such tanks, ranging in size from 1000 to 30,000 gallons (3785 to 113,600 liters) in nominal capacity. (Actual overflow capacities are about 8% larger.) Figure 25 is a panoramic view of a very sophisticated propellent storage system for chlorofluorocarbon and hydrocarbon propellents now in use by the Samuel Taylor (Pty.) Ltd. Division near Sydney, Australia.

A full description of the engineering and safety requirements for propellent storage installations can be obtained from any of the propellent suppliers (see Aerosol Propellents chapter) and would be too lengthy to discuss here. In brief, the propellent is withdrawn from the bulk tank or blending facility and pumped through a welded piping system containing excess flow check valves, excess pressure relief valves, screen filtering equipment, an accumulator and other devices, finally entering the gas house. This structure should consist of a small room, preferably set completely outside the main building and outfitted with explosion-proof equipment (Group 1, Class D for hydrocarbons or Group 1, Class C for dimethyl ether). A typical gas house is shown in Figure 26.

Cans are brought in through the 8"(203 mm) wide aperture at the left, using a hooded conveyor to protect them from rain if they are not already crimped. They are T-t-V or U-t-C gassed in the upper right-hand quadrant of the gas house and then returned through the 8" (203 mm) opening at the right. Experts are strongly divided about the wisdom of including other devices in the gas houses, but in this sketch, space is allocated at the left for the installation of a high-pressure propellent pump and vacuum pump needed for U-t-C operations. The building itself is ideally constructed from reinforced 6" to 8" (152 to 203 mm) concrete (or from concrete block as an alternate), except for one wall

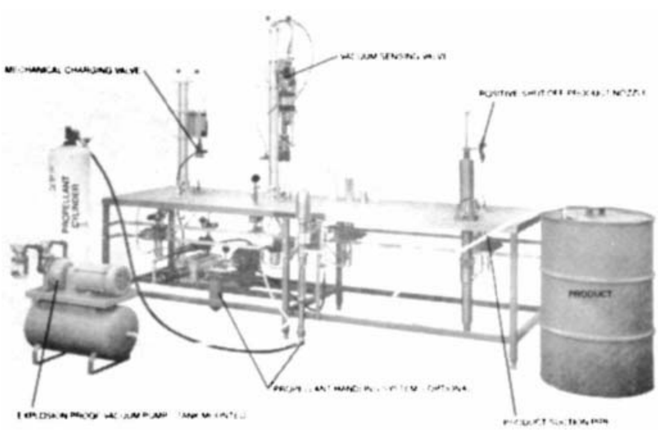


Figure 24. Terco Inc. Hand Operated Filling Machine with Production Heads

Shown at left, front: explosion proof vacuum pump; left rear, mechanical charging valve; center, vacuum sensing valve and propellent handling system; right, product nozzle, product tank.

fitted with blow-out panels held in place with shear-pin fittings. The 2'0" (610 mm) opening provides the fresh air inlet for the ventilation system. Ideally, air is swept across the floor and drawn up into registers just under the blow-out sections. From there it rises through a duct terminating about 10'-0" (3.05 m) above the gas house roof. The gas house should also be outfitted with hydrocarbon gas detection systems (which will also detect dimethyl ether, if that propellent is to be used). This equipment typically uses infrared spectroscopy and microcomputer-controlled components to detect propellent gases and provides read-outs and response modes in terms of percentage LEL (lower explosive limit).

Instrument capabilities range from portable, single purpose analyzers, such as the Sierra Monitor Model 2000 Portable Combustible Gas Leak Detector by the Sierra Monitor Corp., (Sunnyvale, CA), which is sensitive to 25 ppm, but not recommended except for small installations and back-up purposes) to the large, permanently installed equipment by such firms as the Mine Safety Appliances Co., the Foxboro Analytical Division (Norwalk, CT) and the Fenwal Corp. (Chicago). These instruments provide audible, visual and/or electrical interlock alarm operational modes, including complete shut-down of the propellent supply and production facility if the gas concentration becomes too high, typically 50v% of the LEL concentration.

A large number of small, single head aerosol propellent chargers are available, such as the Nalbach Model HPC pneumatic type illustrated in Figure 27.

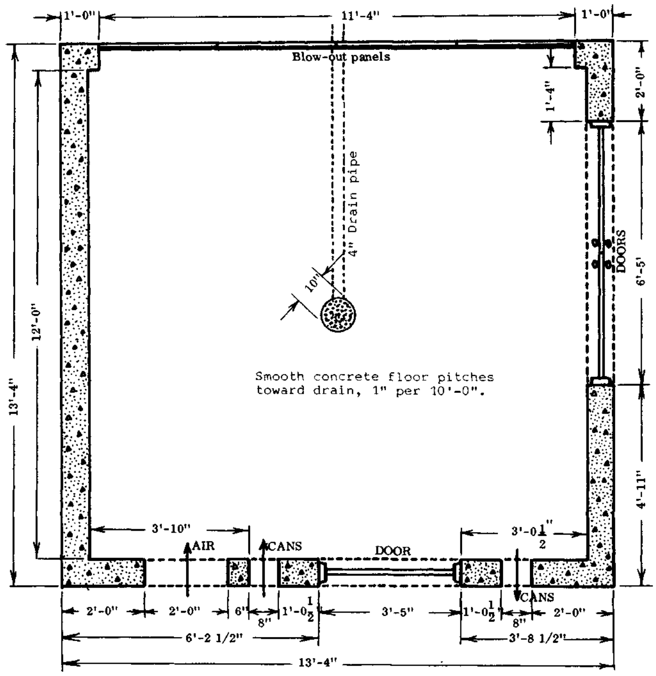
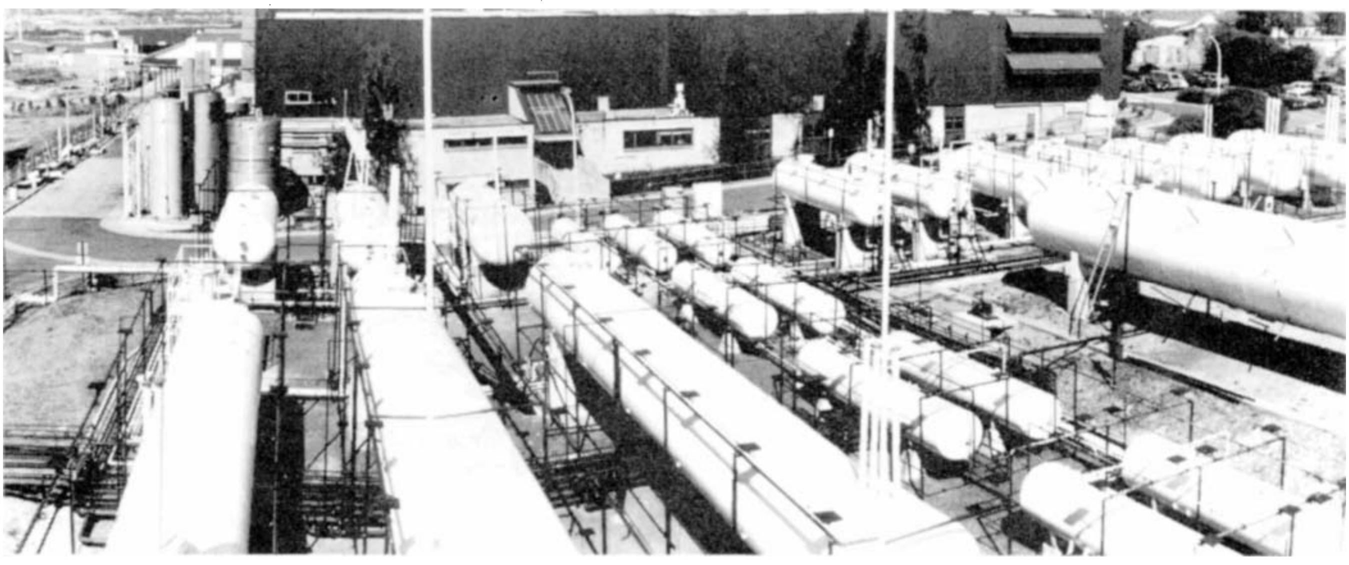


Figure 26. Floor Plan of Gashouse

Figure 25. Propellent Tank Farm

Chlorofluorocarbon and hydrocarbon tank farm. Samuel Taylor Division, (Pty.) Ltd. Sydney, Australia. Illustration shows 22-bulk tanks and protective sprinkler system with heat deflectors over most sprinkler heads. New 30,000 gallon (114,000 liter) storage system is in construction at right.

Imperfections in the photograph are due to compositing three views, indicated by the thin separation lines in the picture.



This particular unit can be supplied with measuring and charging cylinders from the 5 to 50 ml range to the 30 to 300 ml range. Unless the valve is impeded, these hand-operated gassers will easily do 25 to 30 cpm.

For in-line gassing operations, speeds are generally limited to 100 to 140 cpm, on the basis of a double-indexing, double row production facility using four chargers. But for speeds of over about 75 cpm the option of going to a rotary gassing system should be considered very seriously. Some rotary systems, such as those by Terco, Nalbach, Aerofill and Coster are of the "core assembly" type mentioned previously, and as illustrated in Figure 10. But for high-speed production lines, it is best to consider the gasser as a separate functional unit.

Several rotary gassers are available. Through-the-Valve (T-t-V) types are made by Kartridg Pak, Coster, Pamasol and other firms. They appear to be more popular in the U.S.A. than in either Europe or Japan at this time. The Coster Technologie Speciali s.p.a. (Italy) RTV-128 rotary is a high speed machine sold and serviced by AyPak Machinery, Inc. (Closter, NJ).

By far the most popular T-t-V type rotary gasser in the U.S.A. is the Kartridg Pak "small base" line of machines. They are rated at 25 cpm/head (max.) for Model 70 fixed can handling and at 18 cpm/head (max) for Dial-O-Matic can handling, and are available in models carrying 3, 6, 12 and 15 heads. The production rate is determined from the expression:

$$\text{Production Rate} = \frac{\text{Valve Filling Rate (ml/sec)}}{1.54\ \text{Propellent Volume (ml/can)}} \times 60\ \text{sec/min} \times \text{Number of Heads.}$$

For example, for a 240 ml propellent fill and a valve that gases at a rate of 80 ml/sec, a 12-head machine will provide 156 cpm. (This figure is validated by noting that it is under the maxima of either 300 or 216 cpm, depending on the method of can handling used.)

These machines are outfitted with propellent cylinder liners that provide for fills between 4 and 550 ml with a maximum accuracy of ± 0.8 ml, but optional liners can be obtained to provide filling ranges of 2 to 100 ml and 4 to 1000 ml with the same accuracy. (The earlier 1 to 35 ml liner has been discontinued.)

Propellent is normally supplied to the machine pre-warmed to about 100°F (37.8°C) and at a pressure of from 400 to 1000 psig (2.76 to 6.90 MPa). The warming step is useful as a means of reducing the liquid density by 5 to 10% and thus reducing the weight of propellent lost to the gas house atmosphere each time the machine releases a can at the end of the cycle. But it is also important in keeping the various Disogrin, Buna N, Neoprene and Viton gaskets warm and supple, and at their ideal dimensions. (Here it is again noted that Viton and other standard gaskets may be incompatible with dimethyl ether, DME, and they should be checked carefully in this high-solvency propellent, prior to any productions.)

The propellent pressure can be regulated by turning the square-headed screw on top of the line regulator. Below 400 psig (2.76 MPa) there is not sufficient pressure to motivate rapidly key components in the machine. At over 1000 psig (6.90 MPa) machine wear is increased. As a general rule the machines should be run at about the lowest pressure that will satisfy production rate requirements. Many fillers make the mistake of operating in the 1000 to 1200 psig (6.90 to 8.27 MPa) range, using only a small portion of the machine's filling cycle. This is a pointless exercise and increases wear on the moving parts. Measured with a meter or special balloon at any one time, these gassers will almost always show a certain amount of normal propellent leakage. The leakage rate is a lot less at 600 psig (4.14 MPa) than it would be at 1200 psig (8.27 MPa).

The Kartridg Pak "large base" T-t-V gasser is an 18-head machine required only for the very highest speed operations. Under ideal conditions it can easily achieve speeds in excess of 400 cpm. It is a massive

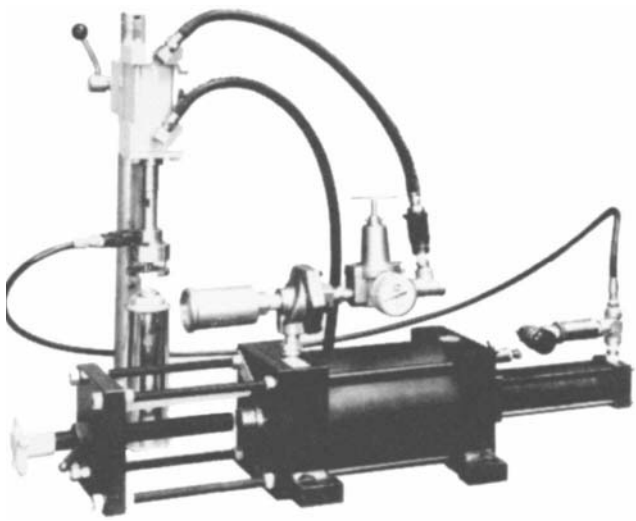


Figure 27. Nalbach Propellent Charger

device, costing over $100,000 and having many constructional and operational differences when compared to the "small base" gassers. Only a limited number have been sold to date.

Perhaps the most commercially successful of all gassers is the Kartridg Pak U-t-C 9-head unit. This machine actually performs three individual functions: air evacuation, propellent filling (around the slightly lifted valve cup) and crimping, as the can revolves within it at speeds of from 3.3 to 27.0 rpm. Figure 28 illustrates the planetary sequences.

In terms of accuracy and reliability it is not a highly effective machine. For instance, the accuracy is listed as ± 2.0 ml maximum, and a number of firms have a program for "beefing up" new U-t-C's when they come in. On the other hand, the high-speed capabilities, flexibility and tripartite operational mode have won wide acclaim, especially in the U.S.A.

From a minimum fill of 4 ml, three charging cylinder liners provide maximum fills of 100 ml (optional), 550 ml (standard) or 1000 ml (optional). The last size, for instance, would be used only for aerosols of a quart (946 ml) or more in size, and where a major proportion of the fill was propellent.

Many aerosol people feel that the 9-head U-t-C will operate at up to 20 cpm per head, but this is only an estimate. The method of can handling, fill size and degree of evacuation versus container head space volume are all important factors. With fixed can handling (Model 70) the 9-head machine will fill up to 180 ml per can at rates up to 25 cpm per head, provided evacuation is not a speed deterrant. This size fill equates to about 100 g for the hydrocarbons and to over 240 g for the chlorofluorocarbons, which is more than most filling specifications. But where fills larger than 180 ml are needed, the maximum rate can be calculated as 4500/fill in ml/head. For example, a 300 ml fill can be delivered at up to 135 cpm for a 9-head machine.

Considering the range up to 180 ml of fill volume, it follows that a 9-head machine should operate up to 225 cpm, if there is fixed can handling and no can evacuation drawback. In practice, many machines have been re-engineered (different sprockets, etc.) to provide maximum rates in the 285 cpm area. Additional wear has to be accommodated by maintenance programming, but this is a modest price to pay for increasing production from 94,500 to 120,000 units in a typical eight-hour (actually 420 min) shift.

For Dial-O-Matic in-feeds the 9-head U-t-C will produce up to 18 cpm/head at fill volumes up to 250 ml. Above this the equation 4500/fill in ml will give the rate.

The U-t-C will draw 20" Hg° (68 kPa) of vacuum in an empty 500 ml can at 18 cpm/head rates, using a 5HP vacuum pump capable of about a 29" Hg° (98 kPa) tank vacuum under no-load conditions. For higher vacuums the speed of the machine must be reduced. It is important to note that the actual vacuum drawn upon the can is not the amount shown by the vacuum gauge on the machine. There is always some loss, in the area of 10 to 15% if good maintenance is observed. To check actual can evacuation levels, the machine must be run under normal "on the fly" equilibrium conditions, but with the propellent flow cut off from one or more heads by merely moving the lever arm of the Jamesbury or other valve at the head. Because of the cost in underfilled cans this quality assurance check is made no more frequently than necessary.

If the associated pumps and drive are considered, the power requirement for a 9-head U-t-C will be 15 HP for a supply of 15 gpm (56.8 liters/min) using a Triplex pump, or 13 gpm (49.2 liters/min) using a Duplex propellent pump, under maximum operational conditions. The machine is used occasionally with 3 or 6 heads on the 9-head frame; and in these cases the power requirement is substantially less although the rating is generally the same.

The U-t-C is an extremely complex instrument. Many options are possible. There are pre-set and pre-

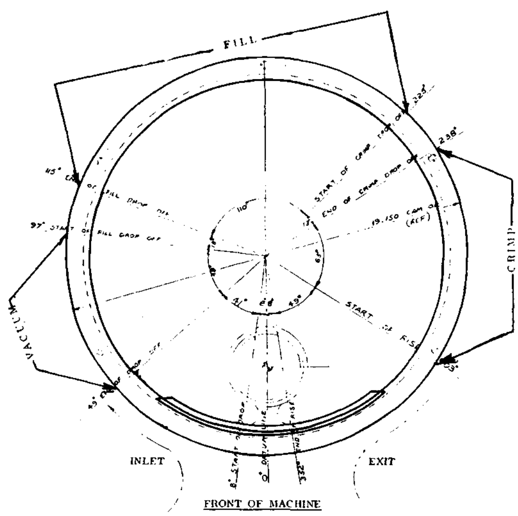


Figure 28. Can Evacuation, Filling, Crimping Sequential Operations of a Kartridg Pak U-t-C Gasser with Nine-Head Frame

open types, molded cap seal and "O"-ring cap seal types, and at least a dozen other variations to handle various propellent types, regular and bottom-filling cans, and so forth.

There are certain hazards connected with the U-t-C, as there are with most complex machines. In one case, a typical machine was operated under conditions where the valve cup was able to be sucked up against the cap seal, thus shutting off most of the vacuum, so far as the aerosol can was concerned. Had the condition been noticed, the maintenance response would have been to turn down the collet pre-set adjustment (to expand the collet in its relaxed state) to the point where a slight drag is felt against the cup. The cup could not then be sucked up to shut off the vacuum. If the lower vacuum seal or the cap seal leaks, the result will be the same: a blow-by will occur and propellent will be drawn into the vacuum hose, where it will evaporate instantly and soon cause hose frosting. In an extreme situation, a large amount of propellent entered the vacuum hose, being drawn into the vacuum pump tank and then compressed out of that tank and into the plant area a good distance from the gassing enclosure. Eventually, the consequences were disastrous.

The machine may be operated in either a right hand or left hand direction, but cannot be converted from one to the other without great difficulty. Can handling is from conveyor to a cast worm screw, and then into either a "fixed can handling" center in-feed and fixed starwheel or a "Dial-O-Matic" center guide and "Dial-O-Matic" starwheel. The "Dial-O-Matic" feature allows for the almost instant conversion of the U-t-C from one can diameter to another, but the speed of the machine suffers somewhat as a consequence. Exiting is by starwheel, which places finished cans on a single-track conveyor. It is at this point that cans are occasionally gouged and perforated, so that powder-containing aerosols sometimes are able to develop a sufficient static charge that the contents can be ignited when a spark leaps to a grounded surface. This is discussed in detail in the flammability chapter.

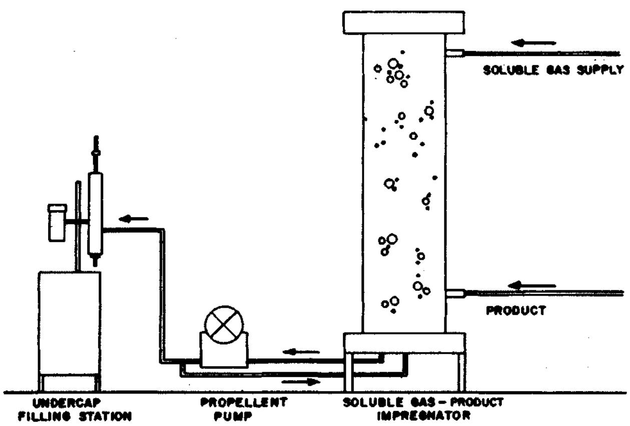


Figure 29. U-t-C and Saturation Unit Layout
Typical Kartridg Pak design

Kartridg Pak also produces a one-head U-t-C, designed mainly for laboratory and small production facilities. It can be hand or conveyor fed and can do 15 to 20 cpm. Larger laboratories often use them to simulate large-scale production equipment. The technique of U-t-C "instantaneous impact gassing" was developed by Paul D. Hughett about 1970, using such a machine at the Peterson/Puritan, Inc. research center in Danville, IL.

Before this development, carbon dioxide (CO_2) and nitrous oxide (N_2O) were introduced into aerosol cans either with a LeMay, Andora, Nalbach or other type of gasser-shaker; or at faster speeds by means of a Kartridg Pak U-t-C system equipped with a "saturator tower". This tower, sometimes called a "soluble gas product impregnator", was used to pre-agitate approximately 40 to 60% of the product with a fixed pressure of propellent gas. Ungassed product entered in one part of the tank and was sent through a baffle system and mixing area, so that it dissolved 88 to 94% of the equilibrium amount of propellent for that pressure and temperature. The gassed product then left the saturator and was fed to the U-t-C as if it were a regular propellent. By using a pressure in the 220 psig (1.52 MPa) area, the final equilibrium pressure of the aerosol would be 90 to 105 psig at 70°F (620 to 724 kPa at 21°C). This system was fairly good for very low production runs, but had a number of problems, such as the loss of all the material in the tower after each run. See the schematic drawing in Figure 29.

The principle of "instantaneous impact gassing" is thought to have been first considered in West Germany, about 1968, for cans fitted with extremely high gassing rate Precision valves. It suggests that the act of blasting high pressure soluble gas into an aerosol can containing a concentrate will disrupt the liquid into something akin to a super thick mist with an enormous surface area; thus facilitating absorption of the gas before the pressure can rise to can-bursting levels of 220 to 280 psig (1.52 to 1.93 MPa), at least in the case of tinplate cans. Experimentally, it was found that when super-fast injection pressures reached about 575 psig (3.96 MPa) the break-up action overcame the pressurizing action and the process was successful, at least where there was at least about 19v% headspace for expansion and mixing, and where the concentrate was not too viscous. The optimum pressure range is 625 to 650 psig (4.31 to 4.48 MPa). Above 650 psig (4.48 MPa) the system still works well enough, but this range may not be attainable with cool CO_2, due to condensation.

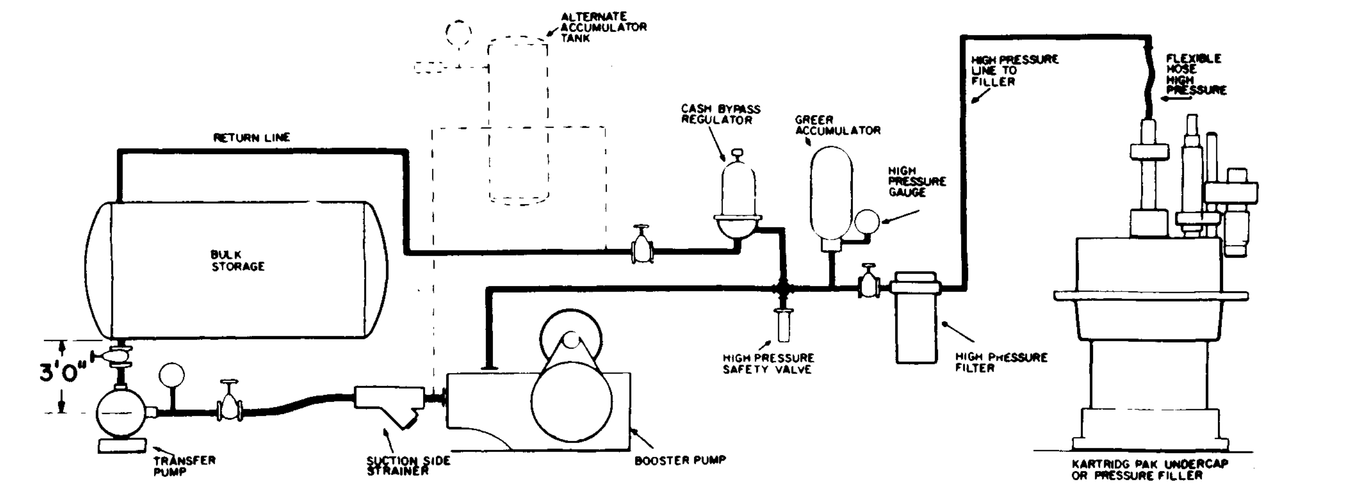
To our knowledge, N_2O has never been gassed into cans by instantaneous impact gassing techniques, except under laboratory conditions, where it works out as well as CO_2. The reason for this lies in its strongly endothermic character, and the worry about decomposition with heat generation and other sequelae. More recently, it has been shown that nitrogen (N_2) can be impact gassed, which was rather a surprise because very few grams of nitrogen can be absorbed by solvents — in the area of 10% that of CO_2 and N_2O. But with very special modifications to the U-t-C this can be done, and has proven very useful for a number of nitrosol products. The engineering particulars used in adapting U-t-C (and T-t-V) gassers to this general type of gassing operation are only partly disclosed in the two existing U.S.A. patents, and there is no reason to delve into this complex matter in these pages.

The Kartridg Pak Company produces an 18-head U-t-C gasser (Model 1967-18), which could be the most complex machine an aerosol filler would ever purchase, and perhaps the most expensive. We would estimate the cost at about $140,000 depending upon choice of accessories and other factors. Few fillers require higher speeds than the 225 to 285 cpm generally afforded by the 9-head U-t-C machines. Even if they do, there is the option of dividing the production line into a "Y" design just ahead of the gas house and using two 9-head machines. We would estimate that only one of the massive 18-head U-t-C gassers is sold for every 40 regular 9-head U-t-C gassers. They should provide speeds of up to 450 to 560 cpm, provided the other line equipment can be up-sized accordingly.

The propellent supply system to any of the Kartridg Pak T-t-V or U-t-C gassers is a fairly complex one. A typical lay-out is illustrated in Figure 30.

Liquid propellent is withdrawn from the bulk tank through a double valve, strainer and then a low pressure transfer pump, where the pressure is increased to at least 15 psi (103 kPa) and preferably at least 60 psi (414 kPa) over the regular vapor pressure. The propellent then travels to the vicinity of the gasser and goes through a second strainer, then a Wheatley or other high pressure booster pump, capable of developing 1000 to 1200 psig (6.89 to 8.27 MPa) and rated at from about 10 to 25 gpm (38 to 95 liters/min) depending on gasser size. A high pressure line then passes a safety relief valve set at about 1300 psig (8.96 MPa) and splits to form a return line to the tank via a by-pass valve and a line going toward the gasser. The gasser line goes through an accumulator and filter, then a pressure gauge (0 to 1500 psig; or 0 to 10.34 MPa) and into a short length of high pressure flexible hose that leads to a Deublin right-hand or left-hand upper rotary union on top of the gasser. The vacuum line also connects into

Figure 30. Propellent Supply System to Kartridg Pak U-t-C Gasser



this union. Check valves have not been mentioned, but are included. Pressure relief valves should be placed everywhere in the system where propellent could be locked in between two valves or other shut-off points, to prevent liquistatic rupturing. And finally, it is very important to place an excess flow valve as near to the gasser as possible, to minimize loss of dangerous propellent in the case of blown or split hoses, fracture of poppets or sudden seal failure. If the excess flow valve is within the gas house the valve relief opening should be piped to an outside location.

The U-t-C gassers make their initial hermetic seal to the can at the flat dust-cover area, or the comparable area, in the case of aluminum containers. A pressure pad above the inner bell is assembled with four "brown" springs (each rated at 175 lbs per inch of compression). The springs are given an 0.065" pre-load compression, so that the set of four creates a force of 45 lbs (20.4 kg). During the initial can evacuation stage, since they do not deflect any more than this, a 45 lb (20.4 kg) force is maintained downwards on the can dome. During propellent filling they are moved another 0.190" (4.8 mm), which allows the inner bell and cap seal to compress hermetically onto the can dome with a force of 133 lbs (60.3 kg). And then finally, for the crimping operation they are deflected an additional 0.440" (11.2 mm) to provide a downward force vector on the valve cup of 308 lbs (140 kg) while still maintaining the 133 lbs (60.3 kg) force on the can dome. The combined downward force on the can is thus 441 lbs (200 kg).

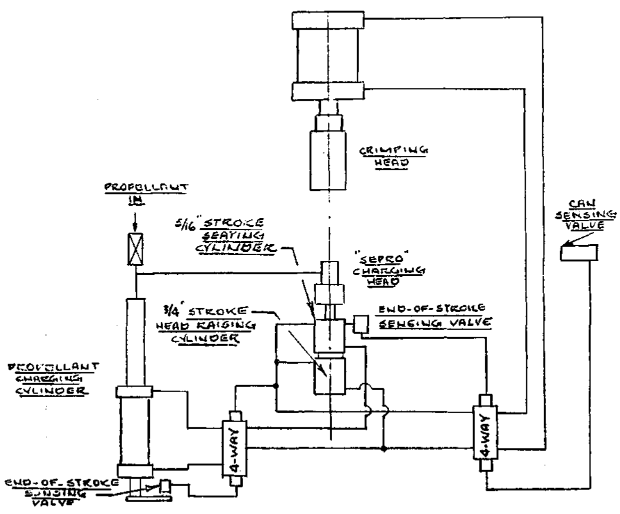


Figure 31. Nalbach Sepro-Charger Accessory for Their Various Rotary Units

In addition to the standard "brown" springs, Kartridg Pak can provide Danley "blue" springs having a 310 lb rating per one inch compression, or even "red" springs with a 790 lb rating. For straight propane A108 or some of the higher pressure butane/propane blends (like A90) the "brown" springs may not provide a sufficiently strong seal at the can dome, and some blow-by may occur, with consequent light fill weights. This can be corrected by using a diagonal combination of two "brown" and two "blue" springs, for a 185 lb (84 kg) full dome compression, or four "blue" springs, for a 236 lb (107 kg) force. Aerosol cans are made with a minimum 285 lb (129 kg) dust shelf crush, so these forces can be tolerated. Theoretically, a force of 133 lbs (60.3 kg) will handle propellent pressures to 64 psig (441 kPa), but in practice they will tolerate somewhat more than that because of differential displacement compression of the seal.

The large downward force exerted in the can during crimping, 441 lbs (200 kg) in the case of "brown" springs, would seem to be sufficient to crush the can. However, the countereffect of the propellent pressure must be taken into account. Nevertheless, many aerosol cans show a clear imprint of the molded cap seal on the arch of the valve mounting cup, indicating the considerable pressures that are exerted at this stage.

In some cases, the U-t-C may be used only as a vacuum crimper, with the gassing being done by a downstream T-t-V or gasser-shaker. Kartridg Pak then recommends the use of four very weak springs (e.g. Associated Products No. CO-720-055-1000) which deflect to a force of only 11.5 lbs (5.2 kg) on the container. No valve cup distortion will then occur from the seal. In using a U-t-C gasser as a vacuum crimper, care must be taken not to bottom out on the third cam operation (springs fully compressed) since the container will then crush from the hydraulic pressure.

The gassing of Sepro cans, from the bottom, can be handled by the U-t-C gassers, provided they are adjusted to perform this function. The necessary accessories can be installed during manufacture, or a field conversion kit can be provided and installed into existing machines. In 1981, the conversion cost for an existing 9-head machine was $33,000, with exchange of the dial housing.

Terco Inc. also produces Sepro can gassers. Their single-head unit will produce 40 cpm at a cost of about $20,000 and a four-head, in-line Sepro-charger (which is still on the drawing board) should run at 140 to 160 cpm and would cost $52,000 in 1981. The propellent weight tolerance is said to be ± 0.5g.

The John R. Nalbach Engineering Co., Inc. also provides an air-operated, automatic Sepro-charger that can be used with their Model 16-RS, Model VB-16 and Model VB-32 rotary indexing machines, Figure 31.

In the "at rest" position the crimping head is up, the Sepro-charger head and the pistons in its two supporting cylinders are down and the propellent charging cylinder piston is retracted and ready to charge. When the indexing starwheel moves the Sepro can into contact with the can sensing valve, the four-way valve on the crimper is shifted and air flows into the top port of the crimping head to perform the crimping operation. At the same time, air flows into the bottom port of the head, raising the cylinder and causing the piston to move up 0.75" (19 mm), which raises the Sepro charging head to seal it against the bottom of the can and open the Sepro valve. Simultaneously, the air flows through the charging cylinder four-way valve and causes the propellent charging cylinder piston to move forward, discharging a pre-set volume of liquefied propellent and forcing it through the Sepro can valve at high pressure.

After charging, the "end-of-stroke" sensing valve is depressed which causes the four-way valve on the propellent charging cylinder to shift. This causes the piston to return to its normal "at rest" position. At the same time, it allows air flow into the bottom part of the seating cylinder. The 0.31" (7.9 mm) motion of the piston in this cylinder seats the Sepro valve. At the end of its stroke, the seating cylinder piston actuates the "end-of-stroke" sensor valve, which then shifts the crimper four-way valve, returning the crimping head and Sepro charging head pistons to their normal "at rest" positions, ready for the next cycle.

In smaller and moderate size operations compressed gases (CO_2, N_2O and N_2) are injected into sealed aerosol cans by means of either in-line or rotary gasser-shakers. The rotary devices made by Autoproducts Inc. (formerly Andora Automation, Inc.) are now considered the standard machines for this type operation and in-line machines have almost vanished. The Autoproducts Inc. rotaries are made in 6-head, 12-head and special 18-head models at a 1982 cost of about $3,600 per head. Typical applications include the insertion of CO_2 or N_2O into windshield de-icers or ether starting fluids, or the injection of these gases into various whipped cream products.

The operating rate is dependent upon valve design. A valve with a restrictive tailpiece or small stem orifice can take a very long time to fully pressurize the can. The machines are rated at about 10 cpm/head, but this rate is for wide-open valves, such as the Clayton and Super-Whip valves. In practice, rates are from 50 to 75% this high for most other valves. The $\pm 10\%$ to $\pm 15\%$ variation of valve orifice diameters (depending upon size) also affects gassing rate. If these valves were to be gasser-shakered for a very long time, such as several minutes, all the containers would come to the same equilibrium pressure. But in actual practice, the dwell time (the time gas is actually injected) is around six seconds, and under these conditions the valves with the larger orifices receive more gas and those cans come to higher pressures.

The gasser-shaker unit is often the speed-limiting device in an aerosol production line, and for that reason various methods are used to try and maximize its output. Increasing the pressure at the inlet is an obvious approach. With the generation of from 90 to 115 psig at 70°F (621 to 793 kPa at 21°C) pressures in the can as the usual goal, inlet pressures of up to about 200 psig (1.38 MPa) have been used to force the gas in more quickly, particularly near the end of the cycle, when back-pressures in the can become significant. However, the higher the inlet pressure the larger the variation in final equilibrium can pressures will be. Factors like exact time of shaking, valve orifice, fortuitous mixing efficiency, line pressure drops and so forth all become more important under high inlet pressure conditions.

Cooling the concentrate generally assists in reducing gasser-shaker time. Whipped cream concentrates are usually filled at about 38°F (3.3°C) to keep the product as fresh as possible; but in some instances, other concentrates are also cooled prior to gassing, to improve rates. For some there will be some optimum temperature between ambient and the practical cooling maximum where gassing is most efficient. Above this temperature, back pressures inhibit gassing rates more, and below it viscosity inhibits gas absorption to a greater degree.

When cans emerge from the gasser-shaker, they are not under equilibrium pressure. There is always a significant surplus of compressed gas in the head space, which will largely dissolve in the product after about two minutes of simple mechanical shaking (as with a Red Devil paint shaker), or about five minutes of fairly vigorous hand shaking, or upon overnight standing. In a production operation the equilibrium 70°F (21°C) pressure can be best determined by noting the equilibrium pressure that results after mechanical shaking, then determining the contents temperature using a "skin type" thermocouple and thermistor, and finally converting to the 70°F (21°C) standard by using a temperature correction factor obtained from a chart.

Hot Tank

The hot tank has always been a vital part of nearly all aerosol production lines, and is actually required for most self-pressurized products under the Department of Transportation (DOT) regulations. With the aim of bringing the can pressure up to at least the equilibrium level for 130°F (54.4°C), the water in hot tanks is maintained at from about 140° to 165°F (60° to 74°C), depending upon product formula, can size and container strength. For instance, the large 300 × 709 (76 × 192 mm) can will sometimes invert at 152°F (67°C) in the case of water-based formulas pressurized with isobutane A-31, and so under these conditions the water bath is best reset at about 145°F (62.8°C).

The hot tank serves to detect leaking dispensers, plus those that are lower than normal in pressure resistance. It tends to clean or rinse off unwanted chemical residues on the can, if any are present. Warm cans are almost always easier to paper label. And from time to time, hot tanking will show up unsatisfactory lithographic work, where for instance the top varnish coat is either missing or too thin, causing tackiness or even running of the print coat.

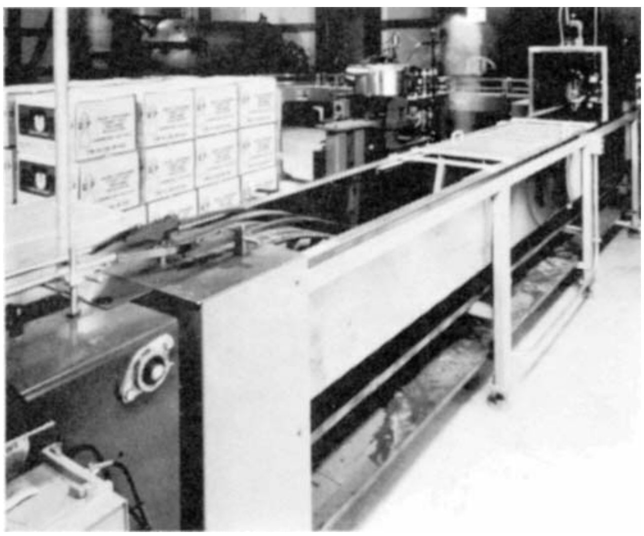
An alert operator is a necessity for proper hot tanking of aerosols. Many cans leak at very low rates. For example, if an operator notes a gas bubble attached to the welded side seam of a can, it should be watched carefully for a few feet (a meter or so) for possible growth, thus indicating a slow seam leaker. If a group of these insidious leakers is spotted, a second operator should be added for still more careful scrutiny. In some cases, the second person merely turns the incoming cans about to make sure the welded side seams are directly visible to the regular inspector. Slow CO_2 leaks are especially hard to detect because the gas is soluble in water. In this case, suspected leakers can be immersed individually in a 20% brine solution, in which the gas is essentially insoluble.

The smallest commercial hot tanks are the three basket and five basket models. They work best where small non-magnetic containers are being produced, but have been used for all other kinds of aerosols as well. The basket consists of a heavy steel mesh square container with a lid of similar construction that can be latched in place. Usually, the basket is dipped in PVC to prevent rusting and any scratching of the aerosol units. It is immersed in the hot water tank and then checked to see if any bubbles are produced by the containers.

The larger hot tanks have from one to six single-width tracks, or else one or more double-width tracks, each split by means of a stainless steel center rail. Squat "horseshoe" magnets are positioned under the metal tracks every few inches (150 mm) or so for hold-down purposes. Otherwise, cans might slide down the end inclines, become floaters or have other problems. The total immersion time varies from 30 to 90 seconds, according to length and belt velocity. Figure 32 illustrates a typical double-row Nalbach hot tank with a capacity of about 100 cpm. The unit is preceded by a Kiwi coder and followed by a Nalbach automatic capper. Protective steel mesh covers are shown at the far end of the trough.

Hot tanks can be rather dangerous appliances if not used and maintained properly. During the 1970s a filler in New Jersey had a chain reaction of exploding shave cream cans that literally almost tore the hot tank in two. Had these cans contained a formula high in hydrocarbon content the consequences could have been even more serious. Many large hot tanks have ventilated

Figure 32. Nalbach Double Row Hot Tank and Can Blower

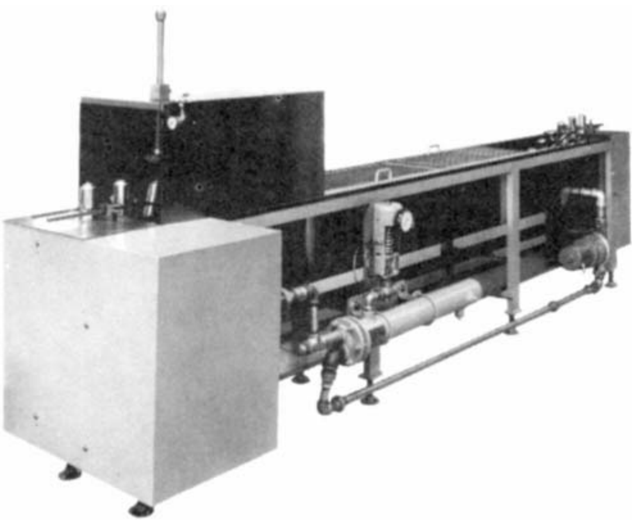


hoods for the quick exhaustion of any hydrocarbon gases released from fast leakers or rupturing cans. The enclosures usually have plexiglass observation ports that can be opened easily to withdraw defective cans and are lighted with explosion-proof fixtures. This type of lighting is available from the Holophane Division of Johns-Manville, Inc. (Denver), and other suppliers.

Most baths are the straight-run type, but a few are of the wide bed variety, where cans move back and forth several times on different conveyor belts before emerging. Some of these tanks are eight or more tracks wide. One problem with such models is that the cans often travel too rapidly, making eddy currents that interfere with inspection. Another is that they are often too far away for good vision and ready removal of defectives. Some baths are equipped with small pincers that grip individual cans and carry them along. This is a good innovation for non-magnetic containers, but is not recommended for over 150 cpm rates.

Most baths are heated with low pressure steam (up to 15 psig or 103 kPa), using steam heat exchangers, or else heat exchangers with electric elements. Others are heated with commercial gas-fired or electric hot water heaters, or with electric elements or steam coils submerged in the tank itself. The cost of heating hot bath water is often neglected or underestimated. It varies with the aerosol load and with the rate of drainage. Not much can be done about the former, but the cycling rate can generally be reduced to a mere trickle if the dispensers are of good quality and are relatively clean going in. In 1981 the cost of steam averaged $4.00 per million BTU in Canada and $5.10 per million BTU in the U.S.A. Aerosol cans require from 10 to about 85 BTU (with a 30 BTU average) for a temperature elevation of 60°F (33.3°C). Considering other losses, from radiant heating, conversion inefficiency, drainage and so forth, a hot tank that uses steam should have a power cost of $300 per million cans. If it uses electric heat, the figure will move up to about $2,000 per million average cans.

Figure 33. Hot Tank Showing Water Heater and Pump
Nalbach Model 1-L1



Blow-off hoods are located at the end of virtually all conveyorized hot tanks. Low pressure air jets blow water out of valve cups and dome countersink areas with varying degrees of efficiency. Many fillers supplement the blower system with high-pressure air jets directed at specific hard-to-dry areas, such as under the rim of the valve cup. These jets are often constructed of 1/8" or 1/4" (3.2 to 6.4 mm) copper tubing, pinched partially off at the end.

It is important to get the can dome and valve cup as dry as possible, and to delay attaching the overcap for as long as practical, to minimize the possibility of rusting. In critical cases, the cans may be heated a little hotter to expedite evaporation of trapped moisture. Most hot tank water is treated with sodium nitrite ($NaNO_2$) to form a solution of about 0.05% concentration, which acts to inhibit can corrosion to some extent. Detergents may also be added to hot tank water for the purpose of promoting drainage and solubilizing any oily residues that may be on the cans. The choice of detergent is broad. Quite often obsolete chemicals are used, if they are available. Figure 33 shows the "back side" of a relatively small Nalbach Model 1-L1 hot tank and serves to illustrate the water heating and circulating system.

Tipping Machines

In some cases, the valve button must be applied by the filler, and this operation is performed either before or after hot tanking. Large size buttons must always be tipped, because the crimping collet cannot ride over them to make the crimp. The acknowledged leader among equipment suppliers in this small area is the Haumiller Engineering U.S.A., Inc. firm. They provide the Liberty and Super Liberty Automatic Spray Tip Applicator, and in 1981 introduced an air-operated tipping machine at a relatively low cost, rated at 90 cpm. The Haumiller machines are compact, feeding buttons onto valve stems from a revolving, vibrating bowl, then hammering them down lightly to seat them properly. Any button orientation must be done by hand.

Capping Operations

Most lines that operate over about 70 cpm are now outfitted with automatic capping equipment. One of the more popular is the "CaPeM" unit, by Consolidated Packaging Machinery Corp. Their Model TG-8-15 provides rates of up to 300 units per minute. Resina cappers and the Pneumatic Scale Corporation's "Pneumacap" machines are also quite popular. Other makes are also available.

One of these is the specialty capper made by Nalbach for "stalk-type" (Clayton and Super-Whip) valves. The caps are applied from a sorting helix, where they are positioned upright and dropped over the valve, they are then centered and pressed down forcefully, enabling the plastic lugs to grip under the rim of the valve cup. The cap placing unit has a Geneva Drive to facilitate a smooth, fast operation. Similar units are made by Aerofill Ltd. and other suppliers. The Nalbach machine is illustrated in Figure 34.

Aerosol Can Packaging

A number of operations take place at the end of the aerosol production line, and many of them are performed mechanically on the larger installations. The aerosol case loader machines replace one line operator for about every 40 cpm of line speed. Cases are set up either by hand or with the aid of a box-maker and are fed to the case packer via a skate wheel or roller conveyor. In the packer, collected cans are dumped into the waiting carton through thin shives. Once filled it is given a sideways shove onto a second conveyor, where it travels to the case sealer.

Roller conveyors used in this area may be energized using a padded chain drive, such as those available from the Rapistan Division (Grand Rapids, MI), their Model 1276, or filled cases may be raised using a rubber-belt conveyor and deposited on a simple skate-wheel or roller type, pitched downward slightly, so that a row of cases can be fed to the case sealer.

In the sealer, normally both top and bottom outside carton flaps are glued, and then closed and compressed against the inner flaps for 30 seconds or so to make the seal. Other sealing options are used less commonly. For instance, the case bottom can be stapled shut with a device such as the Bostitch Division's FC95-B motorized carton bottomer, using wide crown copper-toned staples. Some marketers prefer to use tape to seal carton tops.

During the compression cycle, while the glue seizes, case codes are able to print identifying information on the side or end wall of the box. A few are able to code simultaneously both side and end sections.

Case sealing systems are made by Standard Knapp Corp., the Elliott Manufacturing Co. (Model 68-12), and in England by Paklocker, Ltd. (Andover, Hants). Some of the Standard Knapp equipment is over 40 ft (12.2 m) long.

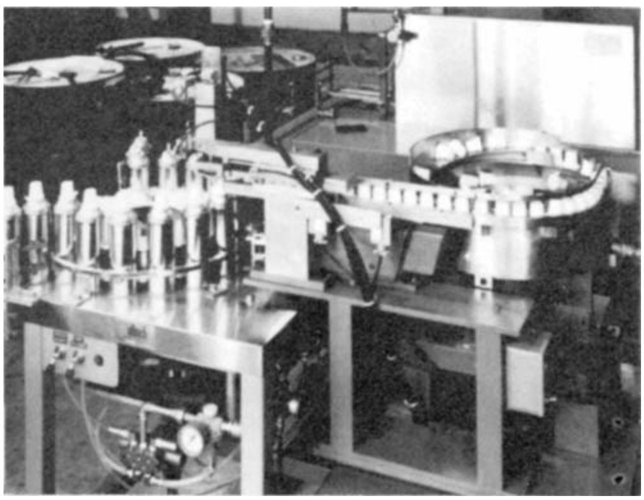
Completed cases are usually stacked on pallet boards by hand, often using a two-sided steel frame to bump the cases against. However, a few firms offer automatic case palletizers, such as the Currie Machinery Co. They are large machines and often become still larger when conveyor in-feeds are considered.

During recent years, pallet wrapping has become fairly popular. Pallet wrapping turntables with a spiral elevator design provide for the ascent and descent of the polyethylene wrapping film. Economical "Victory" and "Commander" machines are available from Stevenson Industries (Chatsworth, CA), and in Europe from Ballinger-Rawlings Ltd (Watford, Herts, England) and Lantau BV in Holland; e.g. their "FLM Savr System".

Future Aerosol Filling and Packaging Equipment

Current indications suggest a trend toward moderate speed, no frills equipment, at least in the U.S.A. Lines are available in the 60 to 120 cpm range, where only 7 or 8 operators are necessary. They can often be purchased for less than $200,000 in 1982 dollars. When they are inevitably compared with high-speed production lines, able to go about twice as fast, using twice as

Figure 34. Rotary Cap Placer Machine and Sorter



many operators, and costing several times as much, it can be persuasively argued that two moderate speed lines may very well offer better overall economics than one large, sophisticated, high-speed line. The smaller lines also provide quicker changeovers and can therefore handle smaller production volumes more efficiently than the high-speed types. Many contract fillers, who use only moderate speed equipment, do not consider the contract fillers with only high-speed facilities as true competitors. They aim for business in the area of 5,000 to 50,000 units per order, knowing that the larger fillers generally "bottom out" between 25,000 to 50,000 units per order, due to the need to flush large tanks, complex handling equipment and fillers, plus the fact that their change-overs may require many hours of work. If a production line must be changed over to a new product during normal production time, then there will be a lengthy period where all the investment in equipment, "brick-and-mortar" and labor produces no income. Considering a high-speed operation running on a two-shift basis, it can be suggested that individual productions of less than 160,000 to 200,000 units will force a changeover during the normal work period. In fact, even with runs of this many units, if the production is started during the work period, a changeover will be required during work on the following day. High-speed lines often produce far less than the theoretical numbers of units, and return on investment (ROI) is often much less than anticipated, simply because of the very high cost of changeovers. As the present high cost of money continues into the 1980s, it is likely that one result will be an increasing interest in the moderate speed production lines.

• During the 1980s increasing attention will be given to the six basic criteria that affect the productivity growth of a plant:

a. Manpower — planning, training, control, reduction of absenteeism.
b. Capital budget control.
c. Quality control/assurance.
d. Purchasing control.
e. Maintenance control.
f. Cost control.

In the manpower area, more attention will be given to management planning, the annual budget cycle, departmental objectives and management performance. Formal training will increase as business becomes ever more complex. Probably 1 to 2% of the total work force will be doing nothing but training for higher positions. Plants will perform productivity objective analyses. They will include lost time due to accidents as a per cent of total hours worked, the absenteeism rate — which is expected to cost the U.S.A. $115 billion and Canada about $9 billion in 1982, or about eleven times as much as strikes — and "idle time" on the job. Most labor utilization figures are calculated only when a line is running and are therefore not a total picture. "Idle time" data should be dollarized. Periodic capacity planning should be undertaken to forecast labor and other needs and thus avoid expensive catch-ups.

In the typical well run aerosol production plant, capital funds are spent about as follows:

a. 16% for existing products — to maintain current capacity.
b. 27% for existing products — to increase current capacity.
c. 44% for cost reduction.
d. 3% for new product requirements.
e. 10% for "necessities" — safety needs, security programs, employee comfort, etc.

During the next few years, other plants may move closer to this balance of interests. For many of them, there will be a decreasing desire to increase current capacity, but to aim selectively more for cost reduction. This will eventually mean the maximizing of profits from operations(PFO) as a primary goal and maximizing return on investment (ROI) as a secondary one.

Quality control/assurance will be increasingly looked upon as a productivity improvement tool, and eventually this will also be applied to a major portion of the research and development effort. In 1982, probably fewer than 5% of U.S.A. aerosol firms maintain any quality control cost analyses. Typical costs in a well run plant now run about 30% for "failure", 60% for "appraisal" and 10% for "prevention" — such as planning, maintenance and improvements. Great stress will be placed toward the reduction of "failure", since mistakes are becoming more and more expensive, and the public is less tolerant of business errors.

The quality control/assurance program should cost about 5% of the direct costs for the average aerosol plant. It will obviously be higher for plants involved in pharmaceutical or food activities, probably approaching 8% or so as a limit. If the cost is greater than these figures, an analysis of the quality oriented activities should be made with reduction of "busy work", scrap analyses, rework activities and so forth in mind. Many plants currently discard over 2% of their incoming components and chemicals as scrap. In one notable instance, a well organized program to reduce scrap from 1.7% to a lower figure was initiated in 1978. Plant personnel were advised of the cost of materials and the cost of plant scrap each month. A second checkweigher was installed on each line, after the concentrate filler. There was more surveillance and more questioning of the reason for scraping cans. By mid-1980 the scrap rate was reduced to 0.66%. The increasingly high cost of materials will make such programs more commonplace during the 1980s.

Under purchasing control, increasing attention will be given to maximizing trade discounts, allowances, rebates and similar benefits. The practice of "ordering well ahead" (to ensure production schedules) will be optimized in view of the high cost of money. Purchasers will increasingly ask suppliers to have their anticipated needs produced and set aside, for shipment no earlier than it is actually required. For example, some propellent suppliers now park tankcars on sidings a few miles from the final destination, so that delivery can be made more expeditiously upon the customer's release. Services of this type will increase.

Maintenance control will be upgraded and many haphazard activities done today will be formalized in the future, such as check-off lists for lubrication schedules and analysis of parts replacement needs to predict minimum future needs and highlight possible problems. Maintenance people will be better trained and organized in their activities, with more attention given to preventive actions than to "putting out fires."

Finally, under cost control there will be increasing use of computer technology to expedite data collection and analysis. Microprocessors will be used more often to smooth and sophisticate production operations. For instance, MPs could speed up lines to achieve optimum conditions or slow down certain sections to allow for possible breakdowns. They can also sense impending motor or drive failures on the basis of variant amperage draws.

A micro-processor-based quality control system will provide a way to reduce errors and labor requirements in weight checking procedures. A typical system, such as that recently afforded by the Syscon Corporation's QCT-1000, will automatically record weight deviations, signal out-of-tolerance conditions for every head of both filler and gasser, and totally eliminate the present need for manual data recording of tare and filled weights.

By 1982, the only chemicals not costing at least \$0.30 per lb. (\$0.66 per kg) in bulk were water, CO_2, the hydrocarbon propellents and some of the lower-grade hydrocarbon liquids. Because of this, there will be added pressures on suppliers of filling machines to increase accuracy as a means of reducing the average concentrate filling weight per can. A few super high accuracy fillers are available, and we can recite as an example the Oden Corporation's (Suffern, NY) Pro/Fill 2000 solid state filler, with digital computer logic controlled process circuitry. This interesting machine exhibits up to $\pm 0.1\%$ accuracy at speeds up to 75 cpm. The filling range is from 0.1 ml on up, and it can handle rather viscous lquids and gels, strong acids and bases, high-foamers and low-foamers, hot fluids and cold fluids, and thixotropic or rheopectic emulsions. It also has an electronically controlled anti-drip system. Expansion modules are available for multiple fill station capability, within the 4.0 gpm (15.1 liter per minute) maximum flow rate per port. Machines of this sophisticated nature will probably replace the "non-electronic"types in time.

During the decade of the 1980s we forsee the commercial develoment of various all-plastic aerosol containers, and their production utilization starting about 1983 or 1984. By the end of the decade, they will probably account for more than 50% of all aerosol containers, mainly because of economics. Eventually even valve cups will be replaced with plastic fitments that hold the valve components and seal onto both the inside and outside of the bottle finish using a thin polyethylene gasketed multiple set of barbs on each surface. The development of these components will have a profound future effect upon aerosol production. The bottom of the PET or other plastic bottle may be shock-jacketed with a magnetic plastic snap-on fitment to facilitate can handling. Special design features at the top of the bottle may allow the survival of U-t-C gassing techniques, but at the expense of extra plastic there. Otherwise gassing will have to be done on a T-t-V basis.

In summary, great challenges lie ahead in the filling and packaging of aerosols, and the industry will survive and prosper by using them to their advantage, as they have done with so many innovations in the past.