Conclusions

The thermal design study for a Pyroceram radome for a Mach 4 missile was successfully conducted. Investigation of the effect on thermal stress of blunting the radome disclosed that little or no reduction in maximum tensile thermal stress may be expected with a 1.35-in.-radius nose. Thus, one cannot automatically assume that the increased drag caused by blunting is justified by the reduction in thermal stress.

Preliminary laboratory tests and later wind-tunnel tests showed that the large compressive stress at the point of the radome would not cause any structural problem. Finally, correlation of strain-gauge measurements made during wind tunnel tests demonstrated that both the theoretical method used to predict temperature gradients and the cylindrical theory used to determine thermal stresses give acceptable results for use in radome thermal design.

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a scientist and his hobby

the TECHNOLOGY of WINE-MAKING

G. H. Mowbray

Wine has been called many things since the first known reference to it in Middle Eastern writings dating from 2100 B. C. To Aeschylus it was "the mirror of the heart"; to Shakespeare, "a good familiar creature"; and to William Gilbert, "a panacea for ev'ry conceivable ill."

The author in his vineyard keeps a close watch on the growth and health of highly prized imported vines.

Others have expressed their feelings less kindly, if no less poetically. Milton spoke of "the sweet poison of miuséd wine"; Pope, of "inflaming wine, pernicious to mankind"; while in Proverbs we are warned that "it biteth like an adder and stingeth like a serpent." No matter which of these positions one espouses—and all of them have merit on occasion—officially, wine is the fermented juice of the grape used as a beverage, or so says the Oxford Dictionary.[1] Federal description, however, is a little more verbose, defining grape wine as "wine produced by the normal alcoholic fermentation of the juice of sound, ripe grapes (in-

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[1] *Oxford Universal Dictionary on Historical Principles,* 3rd ed. (rev.), Clarendon Press, London, 1955.

cluding restored or unrestored pure condensed grape must), with or without the addition, after fermentation, of pure condensed grape must, and with or without added fortifying grape spirits or alcohol, but without other addition or subtraction except as may occur in cellar treatment; Provided, that the product may be ameliorated before, during or after fermentation, by either of the following methods. . . ."[2]

For practical purposes there are only three basic types of wine. They can be denoted briefly as fortified wine, sparkling wine, and natural wine.

Fortified wines are natural wines to which has been added the distilled spirit of the grape, i.e. brandy. They may be either sweet or dry; thus, they may have a sweetness (artificially derived) that may be detectable to the palate, or they may be lacking in sweetness—some say "tart," although this is by no means an exact description. The former are the ports, sherries, muscatels, and madeiras. Basically, they are naturally fermented wines that have been fortified with brandy, with or without the addition of sugar products. They are known generally as dessert or aperitif wines. The sweet ones (port, madeira, muscatel, etc.) are usually served after dinner with fruit or biscuits and cheeses, while the drier ones, most often sherry, are served as appetizers before dinner. The dessert wines usually have an alcoholic content of 18% to 25% and are nearly always sweet-to-very-sweet. The sherries have a similar alcohol potential but generally are described as "dry." This is not to deny the existence of sweet sherries, for there are some, but they are in the minority.

Sparkling wines are epitomized by the champagnes, although there are a great many inferior wines that are made acceptable to some by the addition (naturally or artificially) of carbon dioxide. The latter are sold under various names, usually preceded by the adjective "sparkling." There are many federal restrictions on the production of sparkling-wine beverages that need not concern us here. The production of true champagne is a tedious and time-consuming process that results in a unique drink that is almost universally appreciated. Its effervescence is produced by a carefully controlled secondary bottle fermentation that demands constant care and handling. The resulting product is a wine of about 14% alcohol that has no equal in terms of finesse, finish, and palatability. The desirability of these wines is recognized by connoisseurs as well as by Internal Revenue Bureau agents who tax them exorbitantly.

Sampling red wine to determine its sugar content, G. H. Mowbray is seen here in the cool cellar area where fermentation takes place.

Natural wines are the wines that are produced by the complete fermentation of expressed grape juice. That is to say, all of the sugars in the juice of the grape are converted to alcohol and carbon dioxide so that the resulting wine can be described as "dry." These are the table wines of the world, with an alcoholic content varying between 9% and 13% for the most part. Occasionally, but only very occasionally, their alcoholic content runs higher (to 15%), but these are exceptions. Exceptionally also, they contain residual sugar that has not been converted to alcohol by fermentation, as in the case of sauternes of Bordeau, barsac of the same region, and the outstanding wines of the Rhine and the Moselle in Germany, of which, alas, there are all too few.

The bulk of the wine consumed the world over is natural wine. It has an alcoholic content that does not exceed about 13%, and it may be red, white, or rosé. It is not very intoxicating except in larger quantities than most people are willing to consume. When drunk with a meal it adds a touch of festivity as nothing else can do. In fact, an ordinary meal consumed with wine becomes something extraordinary. The old saying that a meal without wine is like a day without sun has much to recommend it. Today, there is no excuse for the former although the latter cannot be guaranteed under any circumstances, even in California.

Since the basic process involved in the production of any wine begins with a natural wine, that is what will be described here. It is basically a simple one as practiced by our ancestors, but in the name of standardization it has become something less than simple.

A Little Chemistry

In 1810, Gay-Lussac, the French chemist, first described the reaction that occurs when freshly pressed grape juice is converted to wine. His analysis revealed the following:

$$C_6H_{12}O_6 = 2\ C_2H_5OH + 2CO_2.$$

(grape sugar = alcohol + carbon dioxide)

This is the overall expression that says that a quantity of grape sugar in the presence of the proper yeast is converted to a certain amount of alcohol plus some carbon dioxide. While Gay-Lussac's formula is gen-

[2] U.S. Federal Alcohol Administration, *Regulations No. 4 Relating to Labeling and Advertising of Wine,* U.S. Government Printing Office, Washington, D.C., 1948.

erally correct, a great deal of analysis directed toward a more exact determination of the process has occupied wine chemists for the last one hundred or more years.

Careful observation of the above relations indicates that the fermentation process is thus nothing more than a molecular readjustment of the carbon, hydrogen, and oxygen of grape sugar. However, there is much more to it than that. In the first place there are two basic types of grape sugar, namely levulose and dextrose, having the following forms:

LEVULOSE

CH_2OH
|
CO
|
CHOH
|
CHOH
|
CHOH
|
CH_2OH

DEXTROSE

CHO
|
CHOH
|
CHOH
|
CHOH
|
CHOH
|
CH_2OH

Thus, as one eminent writer on the subject has suggested, when saccharomycetes (the fermentation yeasts) give the signal, a wild game of musical chairs ensues, creating chaos out of what had been a somewhat orderly arrangement. When order is again restored, there is wine, and some products have been created that were not in the original solution.

Temperature is very important to the total process because of the influence it exercises upon the rate of molecular exchanges and upon the solubility of various acids.

Theoretically, according to Gay-Lussac's formula, yields of 51.1% alcohol and 48.9% carbon dioxide should be possible from a quantity of grape sugar. In actual fact the alcoholic yield will depend on many things, among which are the amount of by-products, amount of sugar used by yeasts as metabolites, sugars used by other microorganisms, alcohol lost by evaporation, etc. While in the strictest academic sense all of the foregoing is indisputable, still the difference between theory and practice is not monumental. Alcohol yields of from 90% to 95% theoretical are regularly obtained. So, freshly pressed grape juice containing 24% sugar will, with proper handling, result in a wine whose alcoholic content is about 13%.

Grape juice before fermentation contains many things other than sugars, and the proper balance of these is of great importance in determining the character of the finished wine. A general statement about the composition of grape juice, or "must," as it is technically known, follows.

SUGARS—The primary sugars are dextrose and levulose, which are usually present in a 1:1 ratio at maturity. Since levulose is nearly twice as sweet as dextrose, the significance of this ratio is apparent. Fluctuations in the ratio caused by grape variety, climate, or whatever, must be taken into account by the wine maker who desires a standard product. Practically no sucrose (cane sugar) is found in grapes of the best wine varieties, but other types may contain as much as 10%. Traces of other sugars and related compounds such as the pentoses and pectins are usually present.

ACIDS—The biological stability of wine is largely the result of its being buffered to a relatively low pH. Grape must contains two major acids, one of them relatively strong, the other less so. They are *d*-tartaric and *l*-malic, respectively. Other acids present in very small amounts include citric (0.01–0.03%), oxalic (less than 0.01%), and traces of phosphoric. The total acidity of musts is calculated as tartaric acid and may range from 0.3–1.5%. Musts from the best wine grapes register 0.6–1.2%, but climate is an important determining factor. The same grape variety grown in the warm, dry climate of California and on the cool, more humid slopes of the Côte d'Or will yield vastly different total acidities, those from the cooler regions being higher in acidity and thus lower in pH.

The making of wine is a task for many hands, as this series of typical activities clearly shows. The vines must be carefully and frequently cultivated, and willing people must spend long hours picking the fruit and hauling it to the processing

NITROGENOUS CONSTITUENTS—These vary widely with soil conditions, especially with respect to ammonia nitrogen. The nitrogen fractions reported in musts include ammonia, amino acids, amide, humin, phospho-tungstic acid, and protein, among others. Of the amino acids, glutamic acid and arginine are present in significant amounts, while the others, about twelve in number, are less evident; there is great diversity of opinion, however, not only as to amounts but also as to which are actually present in detectable quantities.

VITAMINS—Although vitamins in musts are important primarily as accessory growth factors for microorganisms, some are in sufficient quantity to be useful in human nutrition. Small amounts of vitamin A and ascorbic acid have been reported, the latter only in fresh grapes, however. Thiamin and riboflavin are both present in appreciable quantities, as are pyridoxin (B_6), pantothenic acid, and nicotinic acid. Recent analyses suggest that there is also a vitamin P factor present that may be responsible for the tonic-like qualities attributed to wine.

MISCELLANEOUS—In addition to the constituents noted above, grape musts also contain tannins, pigment compounds, many enzymes, and odorous substances about which relatively little is known, but which play a considerable role in the quality of the finished product.

From These Grapes

Thus, as can be seen, the grape is the most important element in successful wine-making. This has been known for centuries, but the history of the acquisition of this knowledge is a fascinating study in itself. Our forefathers in North America found grapes growing in abundance in the wild state and concluded that this was paradise indeed. They soon had cause to revise their opinion because the native grapes produced a bitter, sour wine with objectionable and unfamiliar flavors. Today we call them "foxy" wines. They spent literally millions in their efforts to import the European grape (*Vitis vinifera*) and make it grow in this unfavorable climate. Without going into any great detail, the upshot of it all was that every attempt failed. Therefore, grape culture was virtually abandoned except by the Spaniards who invaded California and who, for the purpose of the Sacrament, persisted in producing an alcoholic beverage from the Mission grape to serve their religious purposes. California wine growers to this day suffer from the zeal of those early devotees. For in truth, the Mission grape leaves much to be desired as a source for wine production, and we can only conclude that those pioneering devouts cared little for what they drank so long as it was red and contained alcohol (as a preservative, of course). The poor reputation of pre-prohibition California wines can be traced largely to the early introduction of this grape into the area.

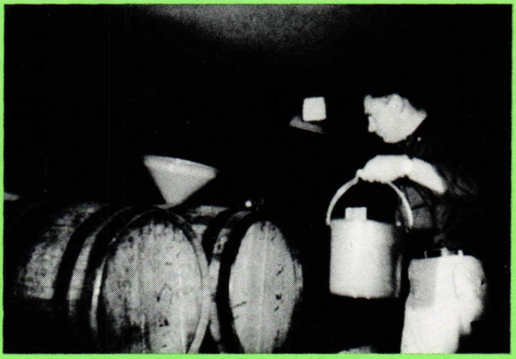
A few centuries after the settlement of North America the Europeans felt the real brunt of Columbus' inquisitiveness. A tiny root louse, called phylloxera, native to these soils but unknown to the rest of the world, was introduced to the virgin soils of France. The result was the total devastation of the magnificent vineyards that had been the pride of the nobility since the days of the Capets. The extent of the catastrophe is difficult for us to imagine—we who have never known the great pre-phylloxera wines.

Within a few years *all* of the vineyards of France had been replanted on grafted American rootstock that was resistant to the root louse. In addition, a vigorous program of hybrid development was begun that produced literally thousands of varieties of grapes that were resistant not only to phylloxera but to extreme climatic conditions and unfavorable soil characteristics as well.

It is the latter development that is of interest to us. These hybrids, genetic mixtures of the old-world strains and disease-resistant American stock, have produced varieties that not only thrive in unfavorable conditions, but also produce grapes from which European-type wines can be made. Thus we are now in a position to accomplish what our forebears sought in vain to do.

My personal interest in wine stems from a lengthy stay in Europe where I completed my graduate studies, but my active participation in grape culture and wine making is the direct outcome of the pioneering

area. There the grapes are crushed and stemmed before being fed into a hydraulic press to extract the juices. These, finally, are poured into oak casks for the long fermentation and ageing processes that turn the grape juice to table wine.



efforts of others. The French hybrids were introduced into Maryland about three decades ago and, following much painstaking experimentation, several varieties have proven compatible with local climate and soils; so much so that a small but growing wine industry has been developed with them. I learned of this less than ten years ago and almost immediately began planting my own vineyard. The results have been so favorable that my enthusiasm for the venture has increased over the years in direct proportion to the quality of the wine we can produce. Being an experimenter by inclination, which is to say compulsive, I am always seeking ways to improve what is even now a very good thing indeed. Consequently, new varieties of grapes are constantly being tested. That is all part of the fun, for who knows but someday Maryland may rival California in the quality if not the quantity of its wine. Some say we already have.

The Process

The actual process of making wine has not changed basically since its first discovery, probably by accident, many millenia ago. The freshly harvested grapes are brought to the winery where they are crushed and pressed and allowed to ferment for a period of time. Formerly, the fermentation was left to the natural, wild yeasts that every grape collects, willy-nilly, in its progression from a hard, green, pea-like growth to the rich golden or purple lusciousness of full maturity. Today, in most wineries, the fermentation is not left to the vagaries of whatever yeasts may have chanced to settle and multiply on the grapes. Instead, yeast cultures of predictable characteristics are introduced early, and they soon marshall their forces, aided by the addition of stupefying potassium bisulfite to the must, to predominate in producing the flavor characteristics common to the type of wine being produced. These cultured yeasts have been developed through the years to have a high sulfur tolerance, hence they are little, if at all, affected by the addition to the must of the sulfurous antiseptic.

Within a few days—the actual time depending upon the ambient temperature—the sugars in the grape juice are converted to alcohol and carbonic acid gas, as previously mentioned. Since this process requires oxygen for its fulfillment, the fermentation containers have been only partially filled. When fermentation is complete, as determined by measurements for residual sugars, the containers are filled to capacity and tightly sealed—or sealed with a water valve to allow gases to escape but prevent any oxygen from entering. This completes the primary fermentation. Technically the resultant liquid is wine, but a sip would tell you that it is far from ready to drink.

At this point, the wine has a yeasty flavor, is thin and exceedingly acid. Throughout the next few months it is left to age—this consisting primarily of settlement of the solids in the wine and a secondary fermentation that consists of a partial conversion of the malic acid to the softer and more palatable lactic acid. This is the well-known malo-lactic fermentation that wine makers of France and the Eastern United States so desire but that the Californians avoid like the plague. Because of the initially lower acidity and higher pH of the Californians' grapes, any further reduction of acidity such as occurs in the malo-lactic fermentation is to them pure anathema; this second fermentation only serves to further flatten the taste.

The malo-lactic fermentation is not completely understood, but some experts believe that short-rod or coccus-type bacteria are involved. It is without doubt an anaerobic reaction that is temperature-dependent, the optimum temperature being between 60° and 70°F. The two probable reactions are as shown in the box below.

Within a few months in a cellar of the proper temperature, the wine has completed its secondary fermentation and the solids have been precipitated, leaving a liquid that is clear and limpid.

At this point the wine maker carefully removes the liquid from its sediment by siphoning or pumping. This assures that unwanted flavors and tastes will not be derived from the deposits of dead yeast cells, tartrates, and other precipitates that have accumulated in the bottom of his casks. Each of these siphonings is accompanied by a measured dose of sulfur to ensure that unwanted bacteria are destroyed and that oxygen reduction does not occur. Certain anaerobic bacteria, particularly the long-rod variety, can completely spoil wine within a few days, while exposure to oxygen in unwanted quantities can render a wine flat and insipid, giving it a madeira-like flavor, highly esteemed for certain types of wines but objectionable in dry table wines.

From this point on ageing is the only reason for not selling the product so laboriously derived. The slow exchange of oxygen through the casks (usually oak or redwood) completes a process that was begun with the proper maturation of the grape on the vine. For red wines of prime

$$\underset{\text{(malic acid)}}{\begin{array}{l}CH_3COOH\\ |\\ CHOHCOOH\end{array}} \xrightarrow[-H_2]{\text{DPN malic dehydrase}} \underset{\text{(oxalacetic acid)}}{\begin{array}{l}CH_2COOH\\ |\\ COCOOH\end{array}} \xrightarrow[-CO_2]{\beta\text{ decarboxylase}} \underset{\text{(pyruvic acid)}}{\begin{array}{l}CH_3\\ |\\ COCOOH\end{array}} \xrightarrow[+H_2]{DPNH_2\text{ lactic dehydrase}} \underset{\text{(lactic acid)}}{\begin{array}{l}CH_3\\ |\\ CHOHCOOH\end{array}}$$

and

$$\begin{array}{l}CH_3COOH\\ |\\ CHOHCOOH\end{array} \xrightarrow[-CO_2-H_2]{\text{DPN, }Mn^{++}\text{ malic dehydrase}} \begin{array}{l}CH_3\\ |\\ COCOOH\end{array} \xrightarrow[+H_2]{DPNH_2\text{ lactic dehydrase}} \begin{array}{l}CH_3\\ |\\ CHOHCOOH\end{array}$$

WINE-MAKING (*continued*)

quality, such an exchange lasting for 3 to 7 years may be beneficial, while for white wines one or two years at most are all that are needed.

At the end of the ageing period, determined by the type of wine and by the characteristics of the vintage or the year of its production, the wine maker filters the wine by whatever process he may have decided upon, bottles it, and sells it for the future enjoyment of those whose privilege it is to comment and criticize. Whatever their reaction, you may rest assured that year after year he will tend his vines and produce his wines. You may have decided against them, but that will not discourage him, because he drank his wines before you did and found them satisfying.

Chacun à son goût.

PUBLICATIONS

W. H. Avery and G. L. Dugger, "Hypersonic Airbreathing Propulsion," *Astronautics and Aeronautics,* **2**, June 1964, 42–47.

R. H. Cantrell, R. W. Hart, and F. T. McClure, "Linear Acoustic Gains and Losses in Solid Propellant Rocket Motors," *A.I.A.A. J.,* **2**, June 1964, 1100–1105.

S. N. Foner, R. L. Hudson, and B. H. Nall, "Admittance Measurements of Solid Propellants by an Acoustic Oscillator Technique," *A.I.A.A. J.,* **2**, June 1964, 1123–1129.

J. F. Bird, "Massive Condensations in Interstellar Matter and Stellar Associations," *Rev. Mod. Phys.,* **36**, July 1964, 717–747.

R. W. Hart, R. H. Cantrell, J. F. Bird, and F. T. McClure, "Nonlinear Effects in Instability of Solid Propellant Rocket Motors," *A.I.A.A. J.,* **2**, July 1964, 1270–1273.

R. R. Newton, "Orbital Elements from Doppler Tracking of Three Satellites," *J. Spacecraft and Rockets,* **1**, July-Aug. 1964, 441–444.

R. E. Walker and M. Shandor, "Influence of Injectant Properties for Fluid-Injection Thrust Vector Control," *J. Spacecraft and Rockets,* **1**, July-Aug. 1964, 409–413.

HONORS AND APPOINTMENTS

R. E. Gibson, Director of the Applied Physics Laboratory, has accepted appointment as a member of the Technical Committee on Space and Atmospheric Physics of the American Institute of Aeronautics and Astronautics.

R. A. Dickmann, supervisor of Personnel Research and Analysis, the Personnel and Education Group, has been appointed chairman of the Computer Personnel Research Group, a national organization concerned with selection, training, and appraisal of computer personnel.

D. W. Fox, supervisor of the Aeroelasticity and Vibration Analysis Project, is one of three recipients of a joint grant awarded by the Scientific Council of NATO in support of "Research and Collaboration in the Estimation of Spectra Operators."

D. E. Rutz, a member of the staff of the APL Security Office, has been elected chairman of the Baltimore Chapter, American Society for Industrial Security.

A. G. Schulz, a supervisor of the Excitations Mechanisms Group in the Research Center, has been appointed a member of the National Academy of Sciences—National Research Council Committee on Basic Research Advisory to the U. S. Army Research Office (Durham) for a period of three years, with concentration in the field of optics and related research. Retiring from this committee are *S. N. Foner,* supervisor of the Electronic Physics Group and chairman of the Editorial Board of the *Digest,* representing the sub-field of atomic and molecular physics, and *C. K. Jen,* supervisor of the Microwave Physics Group, representing the sub-field of microwaves.

ADDRESSES

F. J. Adrian, "Comment on the Valence-Bond Theory of β Atom Hyperfine Splitting," *American Physical Society,* Washington, D. C., April 27–30, 1964.

R. M. Hanes, "A Story of a Book," *33rd Inter-Society Color Council,* Symposium on Color Education, New York, May 4–5, 1964.

J. F. Bird, "Theory of Massive Gravitational Condensations," *Harvard University Observatory,* Colloquium, May 29, 1964.

R. P. Suess and L. B. Weckesser, "Radome Thermal Design for a Mach 4 Missile," *Ohio State University,* Electromagnetic Window Symposium, June 2, 1964.

A. A. Westenberg, "Application of Quantitative ESR to Gas Phase Chemical Kinetics," *University of Minnesota,* Department of Mechanical Engineering Colloquium, June 2, 1964.

J. T. Massey, "Lasers—Their Operation and Application," *Research Analysis Corporation,* McLean, Va., June 10, 1964.

D. W. Fox, "Lower Bounds to Eigenvalues," *Conference on "Funktionalanalytische Methoden in der Numerischen Mathematik,* MathematischesForschungsinstitut, Oberwolfach-Walke, Schwarzwald, Germany, June 16, 1964.

I. B. Irving and W. J. Billerbeck, "Thermal Problems Involved in Space Simulation," *First International Congress on Vacuum Techniques in Space Research,* Paris, France, June 29, 1964.

D. W. Fox, "Lower Bounds for Eigenvalues of Sums of Resolvable Operators," *l'Institut des Mathématiques Appliqués, l'Ecole Polytechnique de l'Université de Lausanne,* Switzerland, July 6, 1964.

C. K. Jen, Invited Lecture Series on Microwave Spectroscopy, *Academia Sinica,* Taiwan (Formosa), Science Symposium, July-Aug. 1964 (8 weeks).

The papers listed below were presented at the *Tenth Symposium (International) on Combustion,* University of Cambridge, Cambridge, England, Aug. 16–21, 1964:

W. G. Berl, P. Breisacher, D. Dembrow, F. Falk, J. T. O'Donovan, J. L. Rice, and V. Sigillito, "Combustion Characteristics of Monopropylpentaborane Flames";