# VACUUM SAP COLLECTION: HOW HIGH OR LOW SHOULD YOU GO?

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## INTRODUCTION

Vacuum sap collection, common throughout much of the maple region, especially where medium to large modern operations are found, is not without controversy. Questions of how vacuum affects maple sap, syrup and trees have existed for many years, and these issues are perhaps more important today than ever before due to the increasing use of collection systems that can achieve very high levels of vacuum. This article will describe recent research performed at the University of Vermont Proctor Maple Research Center that was designed to answer questions about high vacuum.

The use of vacuum to augment sap collection began in some maple operations soon after the advent of plastic sap tubing in the late 50's. Early systems employed pumps designed for milking or other non-maple applications, resulting in vacuum output that was relatively low, as the pumps were not suitable for sustained operation beyond about 13-15" of mercury (Hg). As well, available tubing and fittings were difficult or impossible to make leak-free, and the vacuum level at the taphole was seldom close to the vacuum level at the pump. Despite these constraints and the difficulty of maintaining a working system, many producers with these "primitive" vacuum systems were encouraged by enhanced collection, especially during periods of slow sap flow. At the same time, researchers studying the relationship between the level of vacuum at the taphole and the amount of sap collected began to report that increasing vacuum levels apparently lead to increased sap yields[1].

Despite evidence of a positive relationship between enhanced vacuum and improved yield, until 10 to 15 years ago, equipment limitations prevented an examination of what we today would consider "high" vacuum. As late as 1989, for example, researchers stated that "the added expense and practical difficulty of attempting to maintain vacuum levels at the tap of greater than 15 in. Hg are not warranted.[2]" Today, many producers would consider collection at 15" Hg unsatisfactory. The maximum achievable vacuum at sea level is approximately 30" of mercury, which is equal to the weight of a column of air sitting over any one spot on an average day. At 2000', the air is thinner and the maximum achievable vacuum is about 28" Hg. Recent technological improvements in vacuum system design and equipment, including oil flood or liquid ring pumps, polyethylene tubing, improved fittings and spouts, and wet and dry line arrangements, have made it possible for maple producers to achieve a vacuum level close to these maximums. For many vacuum users, more is better. In a 2007 survey of Vermont sugarmakers, the average vacuum at the pump reported by 74 vacuum users

was 20.7" Hg and several producers reported keeping vacuum levels at the pump at 24-25"[3]. Producers using more than 20" Hg at the pump averaged 0.3 gallons of syrup per taphole, producers using 1"-19" at the pump averaged .22 gallons/tap, and producers who collected sap in tubing without a vacuum pump averaged .17 gal/tap.

Reports of the benefits of vacuum in terms of sap yield have long been accompanied by concerns about effects on sap and syrup quality. Morselli (1974) summarized several years of research at the Proctor Maple Research Center, which addressed some of these concerns using sap collected at what was then considered "high" vacuum (around 15" Hg at the pump)[4]. She reported that at this vacuum level there was no difference in pH, invert sugar content, phenols or mineral constituents compared to gravity collected sap, and additionally no difference in the syrup color made from gravity or vacuum sap. Possible effects of vacuum on the health of trees remained a persistent question in the minds of some producers and researchers. Studies seemed to show that at moderate vacuum levels, no abnormal cellular constituents, the presence of which might indicate rupture of living wood cells, were added to the sap; but what about at higher levels of vacuum? Additionally, an examination of wood damage (staining) associated with different levels of vacuum might also provide an indication of possible tree damage.

The experiments described below were designed to provide additional

information about sap yield, chemistry, sugar content, and tree damage at vacuum levels higher than were tested in the 1970's. While not addressing every question about the effects of high vacuum, including questions about possible effects on syrup taste, the purpose of this study was to explore some possible limitations of the usefulness of very high vacuum, as well as to illustrate possible benefits.

**MATERIALS AND METHODS**

The study took place in the sugarbush at the Proctor Maple Research Center, located at approximately 1400' on a west-facing slope of Mt. Mansfield in Underhill Center, VT. 30 healthy sugar maples averaging 7.5" DBH were selected for this study; small trees were used in order to facilitate dissection of the trunks for measurement of internal wounding. Trees were divided into 6 groups of 5 trees each, and each group was assigned one of 5 vacuum treatments: 15" Hg, 18", 21", 23" and 25 " while the sixth group served as a control, 0" (gravity collection). Vacuum was supplied to the trees by an oil-cooled liquid ring pump. For treatments where less than 25" Hg was needed, the vacuum from the pump was stepped down using vacuum regulators. Sap was collected in 12 liter vacuum chambers (see June 2007 Maple Digest Small Spouts page 22 for a picture of a vacuum chamber). These chambers allowed collection of sap from individual taps under vacuum; the sap remains in the chamber for volume measurement and sampling until it was manually emptied. Each tree was tapped once on the west side, and a new 19/64" spout and dropline were used to connect the taphole to the chamber. Control trees with gravity collection were attached to vacuum chambers which were open at the top to ambient air.

Sap volume was collected and measured from the start of the season, March 2, 2004, until April 19, 2004. Because the vacuum pump was connected to an automatic start mechanism which turned on whenever sap flowed into the main sugarhouse releaser, the tapholes were subject to vacuum for virtually all the time that the sap flowed. Sap samples were collected for analysis on four dates between March 26 and

April 13. Sap sugar content and pH were measured in the lab with a table top refractometer and pH meter, respectively. For mineral analysis, 0.5 g of each sample was analyzed for calcium, iron, magnesium, manganese, phosphorous, potassium, sodium, sulfur and zinc content by inductively coupled plasma atomic emission spectroscopy.

In order to view the staining associated with each taphole wound, all 30 test trees were cut down in July 2005 and an eight foot length of the trunk with the taphole in the center was brought to the lab. Each trunk section was sawn lengthwise into a 3" wide strip for ease of handling by a sawyer using a portable mill. This strip was then cut horizontally into pieces using a miter saw, starting at the taphole and moving above and below the taphole in 2" increments until the stain was no longer visible (Figure 1). The volume of stained wood associated with each taphole was calculated based on the visible length, width, and depth of each stain.

**Figure1. Sections cut from a maple trunk 15 months after vacuum sap collection. The top section contains the taphole; sections below were cut at 2" intervals and show the diminishing size of the stain with distance from the wound.**

## RESULTS AND DISCUSSION

Total sap volume per taphole ranged from 5.0 gallons (one of the gravity trees) to 32.9 gallons (one of the trees at 25" Hg). When the 5 trees per treatment were averaged together, there was a strong correlation between the amount of vacuum and the amount of sap collected (Figure 2). These results parallel those of previous researchers.

Sap sugar content is notoriously variable; among the 30 test trees it varied (average of 4 dates) from 2.475% for the sweetest tree to 1.1% for the least sweet. There was no significant trend in the relationship between sap sugar content and vacuum level (Figure 3); in other words, sap was not diluted at higher vacuum levels. It is interesting to note that had this experiment been limited to 21" Hg, which was about the achievable limit at the taphole using technology available before the mid-late 1990's, there would have been an apparent dilution effect as more vacuum was

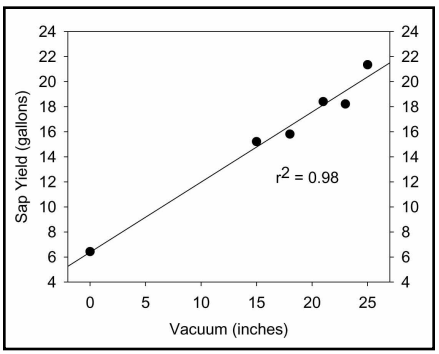


**Figure 2. Relationship between vacuum and sap yield. Each circle represents the average of 5 trees.**

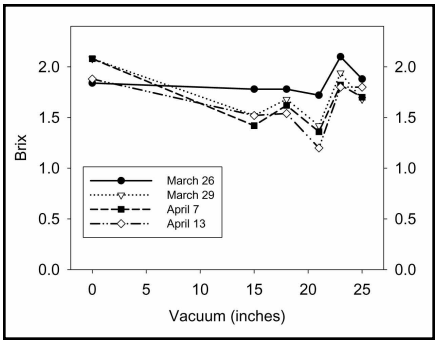


**Figure 3. Relationship between vacuum and sap sugar concentration, measured on 4 separate dates during the sap season.**

applied; however results from 23" and 25" Hg defy this interpretation.

The range of pH from individual sap samples was 5.63 to 8.45, with sap becoming more acid as the season progressed. Average sap pH from all trees dropped from 7.37 on March 26 to 6.42 on April 13; however there were no differences among vacuum levels for pH. Mineral composition of the sap showed no particular trends related to vacuum level (Figure 4). While there was some variability in sap composition among different vacuum levels compared to control sap, there was no indication that increasing vacuum was augmenting or depleting sap nutrients.

Wounds in maple stems , including tapholes, have an associated stain (discolored area) caused by the natural wound response of the tree to invasion of fungi into the wood, These stains can be useful for determining the amount of sap wood in the trunk that is permanently compartmentalized by the tree, i.e. no longer used for sap transport. Tree damage, evaluated as the total volume of the stained wood associated with a taphole, ranged from 25 $cm^3$ to 137 $cm^3$ (for reference, the volume of one foot of 1" mainline is 61 cm3). The average volume of stained wood for each treatment fell within a fairly narrow range. Trees subjected to 18" Hg had the smallest amount of stained wood (less than the gravity trees), and trees subjected to 23" Hg had greatest amount (Figure 5), but trees subjected to 25" Hg had the second smallest amount of stained wood. None of these differences were statistically significant, thus vacuum level had no effect on the amount of visible internal damage to these trees.

This study dealt with many, but not

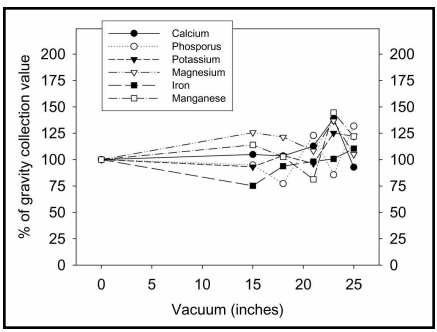


**Figure 4. Changes in mineral concentration of the sap with increasing vacuum. Concentration of each mineral is compared to the concentration in gravity collected sap.**

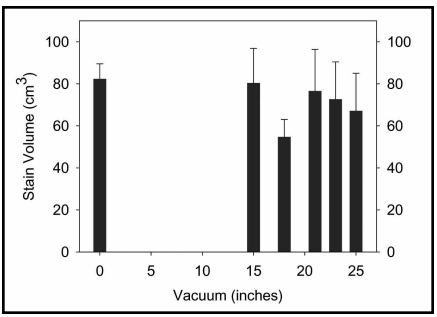


**Figure 5. Relationship between vacuum level and the volume of stained wood associated with the taphole wound. Each bar represents the average of 5 trees.**

all issues surrounding the use of high vacuum sap collection. A persistent question involves the amount of sugar taken from the tree — since vacuum collection permits greater yields from tapholes, would it be possible to remove too much of the tree's carbohydrate reserves? To date, no published study has quantified the total amount of stored sugar in mature maples, due in large part to the difficulty of accurately measuring the huge amount of biomass that must be cut down and excavated, digested, and sampled. Estimates of the amount of a tree's reserves removed from sugaring range from less than 1% to upwards of 10%. Sugarmakers should be reassured however that no studies have documented maple dieback or decline resulting from the use of vacuum for sap collection. Another issue relates to syrup quality. While some producers persist in believing that vacuum collected sap results in syrup that tastes different, many prize winning syrups have come from sap collected under high vacuum. There is certainly room for more research around both of these subjects, as more and more producers discover the benefits of vacuum in their sugaring operations.

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