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Moving Image and Sound:
Basic Issues and Training
VRX-1000

Video Tape Begins in Earnest:
The Ampex Mark IV/VRX-1000/VR-1000

From the earliest days of television, efforts were made to record TV broadcasts. The desire to do so may in the very first place have stemmed from the innate human desire to capture and save that which is inherently fleeting, but the drive to develop a successful system for telerecording was also pragmatic. National corporations with broadcasting interests on both coasts stood to benefit greatly from the ability to repeat programs broadcast live on the East coast three hours later in the West.

As early as 1927, a system of recording a picture signal on a grooved disc was attempted,[1] and that same year it was argued that, due to the comparatively poor capture of detail by video cameras versus those using film, content might be pre-filmed for broadcast. In 1931 the *New York Times* reported on a television broadcast recorded in Schenectady, N.Y.; "no use for movie films of television has been devised as yet," they acknowledged.[2] Pre-filming would not gain prominence until the early 1950s, and kinescopy would not take off for a few more years, but from the late 1930s until 1956, film was by a long way the dominant mediumfor recording TV programs. The kinescope process had many challenges to overcome, from scan

[1]"A Short History of Television Recording" by Albert Abramson.*Journal of the SMPTE*, Volume 64, February 1955, page 72.
[2]"Schenectady-to-Leipzig Television a Success; Movie Also Made of Images Sent by Radio" *New York Times*, Feb 13, 1931, page 15. The article also made the improbable claim that "several hundred feet of film recording the television pictures have been developed, showing equally good or better than the television image itself."

synchronization, to timing frame pulldown during rebroadcast, to faithfully color reproduction. Kinescopes continued in use through the 1960s, and while most of their problems were at least somewhat satisfactorily overcome (NHK in Japan even perfected a three-strip kinescopic color recording process in November 1966,) there still remained the inevitable diminution of picture quality and – far more damning – the at best several hour turnaround involved in processing and reproducing film. Nevertheless, it was the best available option prior to the introduction of videotape, long remained cheaper for such limited archival purposes as were of interest to networks (tapes were expensive, and re-recording on them was irresistible to penny-pinching/budget conscious executives,) and the continued to be the only format usable in countries that had not yet upgraded their television stations to tape.

Magnetic video recording was contemplated at least as early as 1926, when a system was conceived by one B. Rtchcouloffto modifyValdemarPoulsen's wire-recordingTelegraphone to record both sound and moving images. A patent application was made, but the machine is not believed to have been built,[3] and more than two decades would pass before substantial practical work was done on the concept.

When World War II ended, the Allies discovered the Nazis' secret audio tape recorder, the Magnetophon. Two high-end models were captured by the Signal Corps, and two more taken as souvenirs by soldier Jack Mullin[4]. Mullin rebuilt and demonstrated the technology back home in the late 1940s, and when he learned of Bing Crosby's distaste for having to broadcast his radio show live (Crosby preferred to pre-record several programs in one go when the inspiration struck, and none when it did not,) he pitched magnetic recording to Bing Crosby Enterprises as a

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[3]"A Short History of Television Recording: Part II" by Albert Abramson. *Journal of the SMPTE*, Volume 82, March 1973, page 188.
[4]"Creating the Craft of Tape Recording" by John T. Mullin.

flexible, high-fidelity method that would satisfy Crosby, his listeners, and the network. A few years later Crosby hit the same wall with his television program, and Mullin was well-placed in 1950 to propose the development of video tape to solve the problem[5]. Crosby Enterprises was game, and established a lab to develop the new technology. RCA soon also began development on a video tape recorder, and theAmpexCorporation joined the race in1951.Ampex would come out on top with a VTR called, in its various stages, the Mark III (the successful internal prototype,) the Mark IV (which famously brought down the house in 1956 when it was demonstrated to a convention of the National Association of Radio and Television Broadcasters at Chicago's Conrad Hilton Hotel,) the VRX-1000 (used both as the public name for the Mark IV and for the sixteen semi-prototype machines first delivered to networks in late 1956 and early 1957,) and the VR-1000 (the final production model that hit the market in 1957 and continued to be sold into the 1960s.

The Quadruplex Head System

Of all the difficulties inherent in magnetically encoding and decoding video, perhaps the greatest challenge facing the first generation of VTRs was tape speed. To record high quality audio, tape ¼" wide was moved past a stationary head at a speed of 15 inches per second (ips) and written with a magnetic signal modulated by a microphone or other device. To reproduce audio to a high standard of quality requires a signal recorded at about 20,000 Hertz (Hz), or electrical cycles per second. Because of the extra information required to record video, in order to record a signal comparable to that of high fidelity audio, the recorder must write at 5,000,000 Hz (or 5 MHz)! The tape speeds required to capture such a signal are extraordinary: One prototype machine ran at a rate of 360 ips. Such speeds were hazardous to the safety of both

[5]Nmungwun, pages 117-118.

technicians – 360 ips works out to over 20 miles per hour – and to the tape and heads themselves which, like an engineer's hand, could not endure that level of friction for very long. Additionally, it was found that sound which records beautifully at 15 ipscomes out distortedwhen recorded at 20 mph[6].

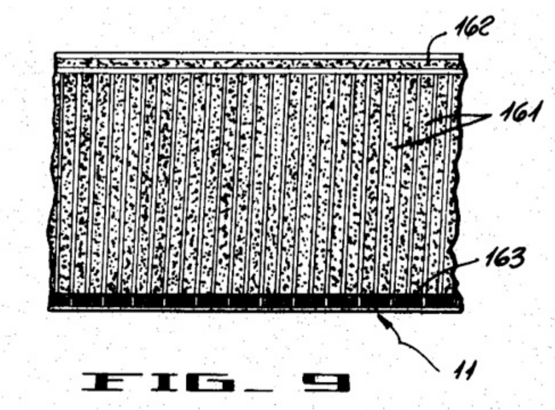
In addition to the Crosby and RCA machines, the first two Ampex prototypes, the Mark I and the Mark II, used this type of problematic longitudinal recording. The solution to the problem, devised by Ampex engineer Fred Pfost[7] and implemented on the Mark III, was both simple and ingenious. A tape two inches wide was run at 15 ips (the standard hi-fi tape speed) past a round assembly containing four video heads, spaced equally around its perimeter. This assembly was positioned transversely to the tape, and spun at a speed of 14,400 rpm, or 240 revolutions per second. Each of the four heads was electronically paired with the head opposite, and the two pairs alternated back and forth so that the head passing the tape was always active. This wrote a series of densely packed (15 2/3mils apart, center-to-center,) parallel, slightly diagonal lines on the tape, which when played back by the same spinning head assembly, strung end-to-end into a continuous signal[8]. The result of this scheme was that despite moving the tape at no greater speed than on a high quality audio deck, the concurrent movement of the tape and the heads worked together for an extraordinary head-to-tape velocity of approximately1,500 ips.The activation of the head pairs overlapped slightly, and the arc of the heads was such that the end of one track duplicated the beginning of the next. Most of this overlap was eliminated when the tape left the video head assembly and passed three additional stationary heads: a pair

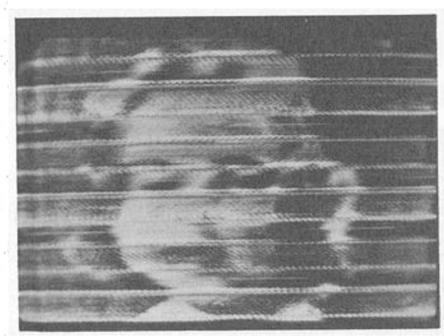
[6]Nmungwun 116-117.

[7] The team that successfully produced the Ampex VTRs consisted of: Charles Ginsburg (chief engineer,) Ray Dolby (more famous for his later work on noise reduction and sound systems, he worked out a lot of the electronics on the Ampex VTRs,) Shelby Henderson, Charlie Anderson (designerof the housing for the Mark IV,) Fred Pfost (developed the remarkable Quad head system,) and Alex Maxey (the brains behind the female vacuum guide, he would later pioneer the concept of helical scanning.)

[8]"Video Tape Recorder" by Ross Snyder, *Electronics*, August 1, 1957.

which first erased a band along the top edge of the tape and then wrote the sound track in the newly vacant strip, and a single head which overwrote (but did not erase) the video signal from a band at the tape's bottom edge. The 15 ips tape transport allowed for the audio to be written at conventional speed, and the remaining picture overlap between the control track and the area just south of theaudio helped to keep the tracks continuous and eliminated the





Track layout of Quadruplex tape.Venetian-Blinds Effect

Image from Patent #3003025

Image Credit: *Video Recording Technology* by Aaron FoisiNmungwun

pervasive "Venetian-blinds" image error. But this Venetian-blinds effect, seen above, could still occur if one or more of the video heads shifted out of alignment. In a piece for the IEEE Global History Network,Pfost explained:

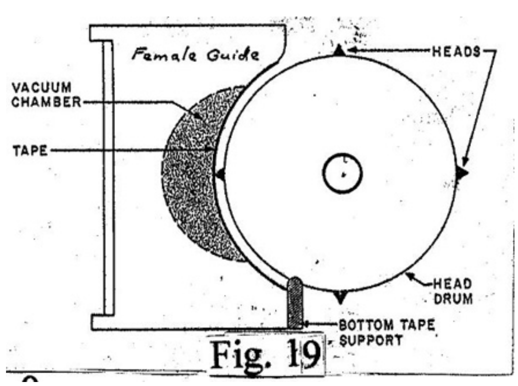
> To give an indication of just how accurate the 90-degrees between gaps had to be, I will put some numbers into the consideration. Our head-to-tape velocity was about 1500 inches per second. In one microsecond a head gap would travel 1500 divided by one million = 0.0015 inch. On a 21-inch monitor the horizontal lines are about 16.8 inches long and this distance is covered by the electron beam making the line in 53.5 microseconds. This calculates out to be (16.8/53.5) = 0.314 inches per microsecond of gap travel. So if the 90-degree position of a gap were off by 0.0015 inch there would be

> an offset in the picture (when one head is switched to the next head) of 0.314 inch and this would be totally unacceptable. Let's say we could accept a displacement on the television screen of 0.01 inch when the head outputs are sequentially switched into the picture.

In order to make this problem correctable,Pfost introduced a designelement whereby each head would be mounted on a very firm spring, which in case of misalignment could be adjusted by turning a tapered screw to exert or alleviate pressure upon the spring and bring the head back into alignment[9].

The “Female Vacuum Guide”

Though the Quad head assembly was the breakthrough that made effective video possible and gave its name to the most famous format of two-inch video, it was not the only clever innovation on the Ampex VTR project. Given the very restrictive misalignment tolerances described above, it will be readily imagined that wow and flutter, irksome enough in the world of



Female vacuum guide.

Fred Pfost, IEEE Global History Network.

[9]"First-Hand: My Ten Years at Ampex and the Development of the Video Recorder" by Fred Pfost.IEEE Global History Network.

audio recording, could cause image disruptions that would be completely unacceptable in a professional television presentation. To stabilize the tape and prevent such errors, the engineers devised the “female vacuum guide” (more intelligibly referred to as the “canoe,”) a scoop-shaped structure which utilized a small suction hose to conform the tape to the shape and position of the head assembly.

The Chicago Debut

Sometime in the later part of 1955, the VTR team demonstrated the current prototype – the Mark III – to a small group of Ampex executives. Up to that time, the project was entirely in the realm of research, and was not considered ready forproduction. Consequently, as Ginsburg described:

> We made no attempt, during this period, to present a “dressed up” machine to anyone and had built, for scientific testing purposes, a rather crude looking wooden cabinet containing a metal top plate and a few electronic units, which operated in conjunction with two partially filled 19 inch standard equipment racks. ... [After the demonstration] it was suggested that we should package our efforts more attractively, since this was going to be a very expensive machine.[10]

From there the team got to work on the new machine, aiming to make it as appealing a piece of hardware as they could manage. Eschewing the breadboards, vacuum tubes, and equipment stacks of the Mark III, the Mark IV was hard-wired, transistor-based, and entirely self-contained

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[10]"The Birth of Video Recording" by Charles P. Ginsburg, LabGuy’s World.

in an attractive and well-stuffed cabinet designed by Charles Anderson[11]. In an article-cum-promotional piece in the *Journal of the SMPTE*, Ginsburg talked up the consistency between the controls and mechanism of the new machine, and those of Ampex's popular professional sound recorders:

> The operation of the machine is in every way like that of an Ampex audio tape recorder. Threading requires less than 30 sec. There are the familiar pushbutton controls for 'Play,''Record,''Stop,''Rewind' and 'Fast Forward.' Provision is made for remote pushbutton control. The buttons even *feel* the same as the controls on an Ampex Model 350, the professional audio recorder which gave its transport and control apparatus to the VR-1000 Videotape Recorder."[12]

Indeed, for such a pile of groundbreaking electronics, and by comparison to many of intimidating-looking Quad decks that would come after it, the Mark IV/VRX-1000/VR-1000 was a genuinely beautiful, elegant piece of workmanship.

This machine was demonstrated in February 1956 to a group of about thirty Ampex executives and employees. In view of their audience, the engineers recorded two minutes of tape, rewound it, and pressed play. Ginsburg reported that when the company men saw what the team had accomplished – saw the future of their company and of television recording – "the entire group rose to its feet and shook the building with hand-clapping and shouting. The two engineers [apparently Pfost and Maxey] who had done more fighting between themselves than the rest of the crew shook hands and slapped each other on the back with tears streaming down

[11] Though the look of the cabinet changed little, the Mark IV was too large to fit through a door, and when the machines went into production they would be reconfigured to be no more than 35 inches deep, small enough to go through a standard doorway. [Reported in Nmungwun, 131-132.]

[12] "A New Magnetic Video Recording System"by Charles P. Ginsburg.*Journal of the SMPTE*, Volume 65, May 1956, page 302.

their faces."[13] Over the next two months Ampex held secret meetings in which it showed off its machine to selected broadcasters and industry professionals. Jack Mullin, still working on the competing longitudinal head machines at Bing Crosby Enterprises, is reported to have seen it and sportingly exclaimed that "It is all over for us! It was a beautiful picture, better than ours!"[14]Throughout this period, as Ampex moved toward a public unveiling of their product, the engineers remained hard at work improving the machine, endeavoring to increase signal-to-noise ratio and making improvements to the video heads.[15]

On April 14 the Mark IV made its sly public debut at the NARTB meeting in Chicago. The vice president of engineering at CBS, William Lodge, took to the podium and addressed two hundred officials from his company. Monitors around the room displayed his image live as he addressed the crowd, saying "now let's see what Ampex has for us." He paused, as if waiting for anAmpex rep to take the stage and show their wares, but instead, after a moment in which the engineers behind a curtain rewound the Mark IV which had been recording the talk, the video of Lodge's words – "now let's see what Ampex has for us" – replayed on the monitors before the audience. One witness reported the ensuing scene this way:

> ... the first thing we knew, after a brief introduction from Bill, we were looking at pictures of ourselves on the monitors not only taken just seconds before, but of a quality that was hard to realize was actually electronically duplicated and not "live." It took a few seconds before we realized the significance of what we had seen, and then, for all the world like a football crowd cheering Doak Walker or Bobby Layne trotting off the field

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[13]Quoted in "The AmpexQuadruplex Recorders" by John C. Mallinson, in*Magnetic Recording, The First 100 Years*, page 158.
[14] Ibid.
[15]"The Birth of Video Recording" by Charles P. Ginsburg, LabGuy's World.

after the winning touchdown, the entire audience rose to its feet and applauded spontaneously.[16]

If this stunt was clearly planned to create a sensation in the room, it is nevertheless true that the response was phenomenal far beyond Ampex'shopes or expectations[17]. The company anticipated that by 1960 it might sell 30 machines at $30,000 apiece – $900,000 in half a decade. Perhaps they hoped that would be a lowball estimate, but by the middle of May 1956, four weeks after the NARTB meeting, they had taken orders amounting to no less than $4,500,000.[18]The company's plan of action then was to build sixteen semi-prototypes, the VRX-1000s, for top customers, and work with those customers to make improvements to the machines ahead of a wider rollout in 1957 so that, as Ginsburg wrote, "next year's production machines [will] benefit greatly from the factory-studio engineering program this Fall."[19] The first machines were delivered in autumn 1956, and the first videotaped broadcast was a November 30 West Coast time-shift of CBS's *Doug Edwards and the News*.

Head Improvement, Interoperability, Etc.

Charles Ginsburg wrote that in the period between the Ampex demonstration and the Chicago debut,

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[16] Quote and details of the event are taken from "The Dawn of Tape: Transmission Device As Preservation Medium"by Jeff Martin.
[17] The dichotomy here between internal expectation and external reaction are interesting, and probably telling with respect to humans' ability to objectively judge the import of their own actions. Where Ampex expected to move 30 machines by 1960, the *New York Times* grandly, though not at all inaccurately, wrote the morning after the unveiling that "although Ampex' first recorder is designed to meet the needs of television networks and stations, the potentialities of the device are virtually unlimited. Undoubtedly it can be utilized by science and industry in many ways for storing and re-presenting all kinds of information."
[18]Nmungwun, 130.
[19]"A New Magnetic Video Recording System," by Charles P. Ginsburg*Journal of the SMPTE*, Volume 65, May 1956, 302-308.

> ... there were many heroes ... but leading them all was Pfost. Fred experimented with the video heads up to the morning before embarking for Chicago. He varied tip structure, core structure, core windings, gap spacing, guide setting, current setting, and continuously built new heads. He accomplished an unbelievable amount of work during this interval. In the last four weeks prior to the Chicago showing, Pfost put in an average of well over 100 hours per week.[20]

Pfost's work on the heads continued throughout 1956 and beyond, and he describes it in significant detail in his piece for the IEEE Global History Network. Concerned with the corrosive effect of tapes' iron oxide particles on the video heads, Pfost researched magnetic substances and learned of "a new extremely hard, highly permeable material (originally developed in Japan) called Sendust." He obtained some Sendust, experimented with it, and despite its extreme hardness, developed a means by which he could machine it into video heads. This extended the useful life of Quad heads from a few hundred hours to several thousand.

For the first two years there were interchange difficulties with the VRX- and VR-1000s, such that a tape recorded on one recorder had to be played back on the same machine with the same head to reproduce a satisfactory picture[21]. By 1959 this had been solved through the regularization of heads, and through developments which allowed for adjustment of both the position and suction of the female vacuum guide.[22][23]

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[20]"The Birth of Video Recording" by Charles P. Ginsburg, LabGuy's World.
[21]Due to frequent mechanical irregularities and faults, it is to this day optimal when possible to play back a videotape on the machine with which it was recorded, but it is by no means necessary in the way that it was with these early Ampex machines.
[22]"The AmpexQuadruplex Recorders" by John C. Mallinson, in*Magnetic Recording, The First 100 Years*, page 158.
[23]Nmungwun, 133.

Color

At the point of initial roll-out, Charles Ginsburg acknowledged that:

> The machines which now exist will not satisfactorily record and reproduce color transmissions, despite their frequency response. There is, however, no limitation whatever in the operating principles of the VR-1000 which will prevent their use for color. ... development has not stopped even on the prototype machines which the networks will have this fall. A large part of our current program is the realization of color recording inhardware –that realization exists now in principle.[24]

For all of the grace with which this admission was made, it must have stung to have to announce it: RCA's system, though it lost the tape race to Ampex's, had been demonstrated in color as early as 1953, and color TV was already coming into its own when the VR-1000 hit the market. But in a remarkable moment of clarity on the part of both companies, RCA realized that it had lost the format war before it even had a viable machine, and Ampex realized that it was behind on color. In mid-1956 the two companies entered a four-month agreement to share access to their Quadruplex and color technologies.[25] The result was that RCA was able to release a viable VTR, the networks were thrilled to avoid a period of competing, non-compatible equipment, and Ampex was able to release a color conversion kit for the VR-1000 one year after the machine's release[26].

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[24]"A New Magnetic Video Recording System," by Charles P. Ginsburg*Journal of the SMPTE*, Volume 65, May 1956, 304.
[25]"The AmpexQuadruplex Recorders" by John C. Mallinson, in*Magnetic Recording, The First 100 Years*, page 160.
[26]*Shifting Space and Time*, by Eugene Marlow and Eugene Secunda, page 18.

Beyond the VR-1000

The VR-1000 enjoyed a long life, remaining on the market into the mid-1960s when it was replaced by newer models Quad models. The modularity that Ginsburg boasted of in relation to color kept it a viable machine long past the time when it might otherwise have become obsolete, as it was an eminently upgradable machine. Some of the original VRX-1000 prototypes remained in service into the 1970s, and two inch Quadruplex, the tape format created for the VR-1000, continued in use into the early 1980s, when it was at last definitively superseded by one inch video, Umatic, and Betacam. While the format is obsolete today, some working VR-1000s remain in circulation[27], and a huge quantity of Quad tape is still out there and in need of digitization. Loss of signal is a real concern, but many early Quad tapes still play like new. The greatest worry is for the equipment: only one company, Videomagnetics, remains to refurbish Quad heads, and we cannot plan for them to keep it up forever. We have now only to do what we can to save as much material as possible from that long era while we still can. But as for the Mark IV/VRX-1000/VR-1000 itself, so long as videotape recording goes on, its legacy endures.

[27] One, highly modified in its first life and restored after a long dotage in a chicken coop, can be seen in action here at the Museum of Broadcast Technology: http://www.youtube.com/watch?v=hGI-cMqSf-g

Annotated Bibliography

Daniel, E. D., Mee, C. D. and Clark, M. H. *Magnetic Recording: the First 100 Years*. IEEE Press, 1999.

- Provided long and veryinformative sections on videotape recording, from the earliest days, covering the Ampex machines extensively, and winding up on the post-VR-1000 world.

Nmungwun, AaronFoisi*Video Recording Technology: Its Impact on Media and Home Entertainment*. L. Erlbaum Associates, Hillsdale, NJ, 1989.

- Nmungwun's book is eminently readable and to the point, while also covering certain subjects – Jack Mullin's work at Crosby Enterprises, Ray Dolby's military situation, dimensions of the VR-1000, etc. – that are not heavily trodden by other works.

Marlow, E. and Secunda, E. *Shifting Time and Space: the Story of Videotape*. Praeger, New York, 1991.

- Provided some good initial background, but ultimately proved to have little information not duplicated in other sources.

"Schenectady-to-Leipzig Television a Success; Movie Also Made of Images Sent by Radio", Special to The New York Times., New York Times (1923-Current file);Feb 13, 1931;ProQuest Historical Newspapers: The New York Times (1851-2009) with Index (1851-1993), pg. 15

- A pleasantly quirky background story, all the more joyful for its taking place in Schenectady.

"First-Hand:My Ten Years at Ampex and the Development of the Video Recorder," by Fred Pfost. http://www.ieeeghn.org/wiki/index.php/First-Hand:My_Ten_Years_at_Ampex_and_the_Development_of_the_Video_Recorder

- At once very personal and very technical. Provided anecdotes and facts not found elsewhere.

"LabGuy's World: THE BIRTH OF VIDEO RECORDING" by Charles P. Ginsburg.http://www.labguysworld.com/VTR_BirthOf.htm

- Less technical than Pfost's piece, and provides more of an overview of the whole project than anPfost's perspective, but beautifully written, and a bounty of information.

Tonbandmuseum. "Die Story überAmpex." http://www.tonbandmuseum.info/ampex-story-teil1.html

- Good initial reading on Ampex.

"AMPEX VRX-1000, 2" Video Tape Recorder, 20th Anniversary with Ray Dolby and AMPEX Engineers at NAB 1976." http://www.historyofrecording.com/ampexvrx1000aniv.html

- Not a great deal of information, but wonderful pictures of the machine and the engineers smiling together 20 years later.

"Creating the Craft of Tape Recording" by John T. Mullin.http://www.bext.com/Mullin-RPT.pdf

- Excellent first-hand account of the roots of postwar magnetic tape development.

"Videotape—Past, Present, and Future" by Jerry P. Zaludek, SMPTE Mot.Imag J. April 1, 1982 vol. 91 no. 4 356-360.

- A good overview of formats.

"A New Magnetic Video Recording System," by Charles P. Ginsburg.*J SMPTE* 1956, 65:302-308.

- A lovely, eloquent write-up on and promotion of the VRX-1000.

"New Products."*J SMPTE* 1954, 62:323-324.

- A nice report on a Crosby machine announced in 1954.

"TV IS PUT ON TAPE BY NEW RECORDER: C.B.S. Will Use Device, Said to ...", By VAL ADAMS Special to The New York Times, New York Times (1923-Current file); Apr 15, 1956; ProQuest Historical Newspapers: The New York Times (1851-2009) with Index (1851-1993), pg. 1

- Unique among sources consulted, as it was written the day of the demonstration by an industry outsider. Only account I read that acknowledged any video errors in the demo.

“A Short History of Television Recording” by Albert Abramson. Journal of the SMPTE, Volume 64, February 1955, page 72.

- A terrific history of television recording that goes right up to the point of video tape, but is published before a practical demonstration has been made.

“A Short History of Television Recording: Part II” by Albert Abramson. Journal of the SMPTE, Volume 82, March 1973.

- Published eighteen years after Part I, this tremendous history picks up where it left off, covering VTRs up to 1973, including a thrilling array of dead-end formats.

"The Dawn of Tape: Transmission Device As Preservation Medium" by Jeff Martin, accessed via NYU website.

- An often philosophical piece on the relation between video recording and archiving. Contains a wonderful account of the Chicago Mark IV demo.

"Video Tape Recorder" by Ross Snyder, Electronics, August 1, 1957.

- Strikes an amazing balance between technical detail and readability. A very straightforward, informative report on the then-newsworthy VR-1000.

U.S. Patents #2916546, 2866012, 2916547, 2921990, 2956114, 2968692, and 3003025.

- Informative in very technical detail on the workings of parts of the VTRs. Invaluable for diagrams.