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THE HEAT IS ON: THERMOGRAMS AS EVIDENCE UNDER THE FRYE STANDARD

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I. INTRODUCTION

Scientific evidence has come to play an increasingly important part in the presentation of cases. In criminal cases, scientific evidence has often replaced traditional methods of gathering evidence, such as interrogation and line-up identifications, which have given rise to fourth amendment concerns.1 In civil cases, where these concerns are not present, attorneys may find that scientific evidence adds credibility to their cases and is even expected by technology-minded juries.

This article will explore the applications of medical thermography as scientific and demonstrative evidence in personal injury cases, with particular emphasis on overcoming the special challenges to admissibility that thermography, as a relatively new procedure, may face in court. Medical thermography is a technique that translates surface skin temperature of a living body, as manifested by infrared radiation emitted by the superficial 5—6 mm. of skin, into a pictorial representation.2 This “picture of heat” can be photographically captured, producing a thermogram.3 Abnormal heat patterns indicate causal pathology or injury,4 and provide objective evidence of pain which may not be otherwise clinically verified.5

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3. Archer & Zinn, supra note 2, at 68.

4. REIN, supra note 2, at 24-1; Archer & Zinn, supra note 2, at 68-69. For a detailed discussion, see infra notes 49-61 and accompanying text.

A. History and Development

Hippocrates is credited with being the first medical practitioner to discover a relationship between irregular patterns of surface body temperature and abnormality. He is said to have coated certain patients with a thin layer of mud which dried first where the underlying skin was hottest, such hot spots correlating with disease. The physical principle which led to accurate measurement of surface temperature differentials was not revealed, however, until 1800, when infrared radiation was discovered. Subsequently, Sir John Hershel, son of the discoverer of infrared radiation, produced the first "thermograph" around 1840 upon developing a process for imprinting the calorific rays of the solar spectrum on a specially prepared surface. The relationship between heat and infrared radiation was further explored, particularly in the context of military applications, during the era of the World Wars. In the mid-1950's an engineering firm under contract to the Army Corps of Engineers developed a high-resolution infrared scanner, which was the direct ancestor of the first medical infrared scanner exhibited in 1963.

Although the relationship between skin temperature and pathology had long been recognized, researchers were hampered by lack of technology that would adequately show surface temperature differentials. Studies in the 1920's and 1930's demonstrated that the skin of the human body emits measurable infrared radiation. Thus, when Lawson suggested in 1956 that abnormalities in surface skin temperature provide a basis for the diagnosis of breast cancer, the stage was set for utilization of current infrared scanning techniques in clinical

6. Rein, supra note 2, at 5-1.
7. Id.
9. Rein, supra note 2, at 5-2; Taylor, supra note 8 at C-2.
10. Taylor, supra note 8 at C-2.
12. Most attempts to assess skin temperature before medical thermography involved placing an instrument on the skin; this itself tended to alter skin temperature, and the process was also affected by the ambient temperature. Taylor, supra note 8, at C-2; Hendler, Uematesu & Long, Thermographic Validation of Physical Complaints in "Psychogenic Pain" Patients, in Rein, supra note 2, at 26-1.
13. Taylor, supra note 8, at C-2.
Medical thermography has been used for over two decades to detect, study, and monitor the treatment of various conditions, including breast cancer, tumors, and vascular disease. More importantly for the personal injury case, thermography has been applied in recent years to evaluate and monitor pain-producing conditions such as whiplash injuries, sprains, low back (lumbar) disk abnormalities, sensory nerve involvement, and soft tissue injuries generally. Within the last ten years, thermographic studies performed on patients with back pain have linked abnormal spinal thermograms with apparently related manifestations in other parts of the body. Most recently, thermography has been used to corroborate subjective complaints of pain where other objective evidence was absent.

B. Test Technique and Equipment

Thermographic measurement is based on the physics of infrared radiation. A body whose temperature is above absolute zero emits infrared radiation. Infrared is part of the electromagnetic spectrum,
which includes visible light; infrared is of a lower frequency and longer wavelength than visible light.\(^{21}\)

The wavelength emitted by a point on an object is a function of temperature; as the temperature of the point increases, the wavelength of the emitted radiation shortens. The human body gives off wavelength of infrared within a certain known range; therefore, in order to detect temperatures in the human body range, a material sensitive to wavelengths in that range is used as a sensor.\(^{22}\) Each of the two methods of thermographic measurement depends on this fact.

Electronic thermography is accomplished by means of infrared scanning. Rapidly rotating mirrors scan the body surface and direct the emitted radiation to an infrared sensor, which collects this "information" and converts it into electronic signals. These signals are processed into black-and-white or color signals and projected onto a television monitor viewed by the examiner.\(^{23}\) The images can be preserved by mounting an ordinary 35 mm or Polaroid camera or video recorder on the machine.\(^{24}\)

In color electronic thermography, the operator controls the color sequence and can change it as he desires.\(^{25}\) For this reason, a color scale appears in each picture, showing the colors for that image in order from the one representing the hottest temperature to that representing the coldest. The actual colors have no intrinsic meaning; red tones, for example, do not necessarily mean "hot."\(^{26}\) The operator also selects the "window" or temperature range that the machine will view.\(^{27}\) By doing so, he sets the sensitivity of the color scale. For instance, on a machine with ten color bands, each color would repre-

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22. *Id.* at 6-2.
23. *REIN*, supra note 2, at 19-1.
24. *Id.; INFRAMETRICS, THE FORENSIC SPECIAL 1*.
27. An electronic scanner may have a temperature measurement range of \(-30^\circ\text{C}\) to \(230^\circ\text{C}\). Most of this potential is useless in measuring emissions from the human body. The operator may select a viewing window of \(10^\circ\text{C}\) — the window can be adjusted up or down to accommodate individual idiosyncracies. The \(10^\circ\text{C}\) range is adequate to show significant temperature differences. See infra text accompanying notes 69-86. The operator will select a window such that the background to the image (i.e., the room in which the thermography is performed, whose temperature is controlled, see infra notes 63-65 and accompanying text) is outside the viewing range and is imaged as black. Selection is not made on the basis of the patient's skin temperature per se (which is irrelevant because it is differences in temperature, not degrees of heat, which are significant, see infra notes 49-50 and accompanying text) but rather is aimed at blacking out the background and obtaining maximum contrast in significant body areas.
sent ten percent of the total temperature range being viewed. A viewing window of 10°C means that each color would represent a 1°C difference from its immediate neighbors on the color scale.\textsuperscript{28}

In black and white electronic thermography,\textsuperscript{29} a calibrated gray scale is built in, leaving the operator only the option of showing “hot” as either bright or dark.\textsuperscript{30} Temperature differences are indicated by a continuous scale of gray tones rather than by colors.\textsuperscript{31}

The other method of thermographic measurement, known as contact or liquid crystal thermography (LCT), depends on the sensitivity of certain cholesterol derivative crystals that selectively reflect infrared light in a narrow range of wavelengths.\textsuperscript{32} Each type of crystal used has a specific color response to wavelength temperatures that are emitted from the human body.\textsuperscript{33}

The apparatus used in contact thermography consists of a sealed box, one side of which is a flexible, transparent sheath in which sensitive crystals are embedded. The remaining sides of the box are rigid, transparent plastic frames.\textsuperscript{34} Air pumped into the box allows the sheath side to function as an air pillow, which is placed directly on the subject and contours itself to the subject’s body.\textsuperscript{35}

A number of LCT boxes are available, each with a slightly different temperature range. This allows the operator to select the box with the widest display for the subject’s skin temperature. The operator initially uses a box with a median Celsius temperature range of 30°C. If “cold” colors predominate, the skin temperature is too cold for that range, and a 28°C box must then be used for a wider color display.\textsuperscript{36} This procedure is analogous to the selection of a viewing window in electronic thermography. In contact thermography, the color scale and its sensitivity are fixed by the chemical composition of the crystals, and thus are not controlled by the operator.\textsuperscript{37} The subject’s body

\begin{itemize}
\item \textsuperscript{28} Wexler, supra note 25, at 28; INFRAMETRICS, supra note 24, at 1.
\item \textsuperscript{29} Black and white is preferred for certain purposes, see infra note 83.
\item \textsuperscript{30} INFRAMETRICS, supra note 24, at 1-4.
\item \textsuperscript{31} Id. at 1-8.
\item \textsuperscript{32} REIN, supra note 2, at 19-1; Pochaczevsky, Wexler, Meyers, Epstein & Marc, Liquid Crystal Thermography of the Spine and Extremities, 56 J. NEUROSURGERY 386 (1982) [hereinafter cited as Pochaczevsky].
\item \textsuperscript{33} Pochaczevsky, supra note 32, at 386.
\item \textsuperscript{34} Id. at 387.
\item \textsuperscript{35} Id. This apparatus replaced earlier contact methods, which involved painting the crystals directly onto the skin, or using rigid plates impregnated with crystals. The former method yielded unreliable results, while the latter did not contour well to the body. Taylor, supra note 8, at C-4.
\item \textsuperscript{36} Pochaczevsky, supra note 32, at 387.
\item \textsuperscript{37} Wexler, supra note 25, at 28. The LCT color scale, from coldest to hottest, be-
heat causes a color image to appear on the liquid crystal sheath, and the image is immediately photographed.\(^{38}\) These two methods of thermography, electronic and contact, correlate well as both are essentially performing the same function.\(^{39}\)

C. **Thermography's Unique Value in Personal Injury Cases**

Thermography can be of particular value in personal injury claims. Not only are thermograms dramatic and graphic illustrations of injury, but thermography provides objective evidence of otherwise unexplained pain. Thermography can document soft tissue injuries such as sprains, whiplash injuries, and low back sprains which are not revealed by other diagnostic methods.\(^{40}\) It is a completely objective method to document trigger points and resulting areas of referred pain (termed myofascial pain syndrome).\(^{41}\) It is also the only objective test capable of identifying sensory nerve damage, which can cause pain in areas other than the immediate locus of the affected nerve root.\(^{42}\) Thermography can detect and demonstrate organic disorders that
gins with dark brown and progresses through light brown, red brown, yellow, green, light blue, and dark blue (hottest), in that order. Wexler, *supra* note 25, at 28. An example of color range sensitivity calibrations in one LCT box is as follows: Dark brown, 32°C; light brown, 32.3°C; red brown, 32.7°C; yellow, 33.6°C; green, 33.7°C; light blue, 34.6°C; and dark blue, 36°C. Pochaczevsky, *supra* note 32, at 389.


41. *Id.* A "trigger point" is an area within traumatized muscle tissue that is capable of referring pain to otherwise normal tissue which is anatomically distinct from the source of the initial trauma. A trigger point may be "silent," that is, display no clinically detectable abnormality, yet still be capable of referring pain to otherwise normal structures when stimulated. The pain associated with such trigger points is termed myofascial pain, and it probably accounts for a significant percentage of undiagnosed, misdiagnosed and "unmanageable" pain complaints. A typical example is whiplash, where cervical (neck) trauma may be followed by referred pain in the hand, arm, jaw, or face. Flashner & Maher, *Cervical Trauma*, in MASS. ACAD. OF TRIAL ATT’YS DIAGNOSTIC MED. PROC., at A-2, A-3. The painful areas show no local pathology and have normal function. Fisher, *supra* note 17, at 22-3.

might otherwise be, and often are, dismissed as psychogenic pain, the product of the complainant's imagination.43

II. SCIENTIFIC FOUNDATIONS AND PRINCIPLES OF THERMOGRAPHY

A. Physiological Basis

Heat is a byproduct of body metabolism, and is distributed throughout the body by the vascular and lymphatic systems, to be ultimately conveyed to the skin and lost through convection and radiation.44 One mechanism regulating surface heat loss and therefore controlling surface skin temperature is the constriction and dilation of the capillaries forming the vascular net that lies just beneath the skin.45 When these capillaries are dilated, they allow increased blood flow in the capillaries and increased perfusion of blood in surrounding tissues, resulting in a quantitative increase in the temperature of the overlying skin.46 Conversely, constriction of the surface capillaries decreases the vascular supply to the affected area and lowers skin temperature.47 It is these temperature variations that are detected by thermography in the form of radiant heat emission.48

Normally, the human body emits heat in symmetrical patterns; any variation from symmetry indicates abnormality and possible causal problems.49 Thermography reveals the presence or absence of such variations; a thermogram thus reveals the function, rather than the anatomical structure, of the body.50

The mechanisms responsible for alterations in surface blood supply are not completely understood, but various theories have been pos

44. Archer & Zinn, supra note 2, at 68; Christiansen, supra note 16, at 7-2.
45. Archer & Zinn, supra note 2, at 69; Christiansen, supra note 16, at 7-2.
46. Archer & Zinn, supra note 2, at 69; Christiansen, supra note 16, at 7-2.
47. Archer & Zinn, supra note 2, at 69, Christiansen, supra note 16, at 7-2.
48. Christiansen, supra note 16, at 7-3. While some studies have suggested that tumors or hyperactive muscles (i.e. muscles in spasm) act as thermographically detectable heat sources, these claims have been questioned; it appears that abnormal heat generated by such sources is probably so rapidly dissipated as to have little effect on the temperature of surrounding tissue. Id. at 7-1 to 7-3.
49. LeRoy, Christian & Filasky, The Role of Thermography in Diagnosis and Management of Chronic Pain, 4 MEDIGUIDE TO PAIN 1, 1-2 (1983) [hereinafter cited as Le-Roy]; REIN, supra note 2, at 24-1; see also Pochaczewsky, supra note 32, at 388-91; Tichauer, supra note 11, at 730; Wexler, supra note 25, at 26.
50. REIN, supra note 2, at 15-2; Meyer & Meyers, Would You Like to Know What Pain Looks Like? 28 LA. BAR J. 77, 77-78 (1980). Other diagnostic procedures, such as myelography and the CAT scan, present two-dimensional pictures of anatomical structures. REIN, supra note 2, at 15-16.
tulated. "Cold spots," caused by vasoconstriction in the affected area, may be the result of noxious stimuli on nerve roots of the sympathetic nervous system where they exit the spine. Such stimuli include irritation, scarring of the nerve root, and pressure on the root. Nerve fibers disrupted by injury may reunify incorrectly during healing so that they transmit crossed or mixed messages. The sympathetic nervous system responds to stimuli in a certain way; the classic sympathetic reaction to stress stimuli includes "fight-or-flight" responses such as pupil dilation, increased blood flow to skeletal and heart muscle, and vasoconstriction in the digestive tract and skin. Where nerve root irritation exists, affected sympathetic nerves remain stimulated and vasoconstriction persists in areas of the body surface energized by those nerves, producing the cool spots imaged by thermography. This process, which is associated with pain, may persist after the original causal injury has apparently healed.

Thermographically-shown "hot spots" have engendered various physiological explanations. The vasodilation that produces abnormally warm areas has been attributed to metabolic changes within certain cells, such as changes produced by tumors, and to muscle spasm caused by irritation of the motor nerves mediating the affected area. Both of these suggestions have been criticized. Another theory postulates the release of a substance that acts as a vasodilator and produces pain when sensory nerves are stimulated. The affected

51. Wexler, supra note 19, at 39; Pochaczewski, supra note 32, at 389; Christiansen, supra note 16, at 7-4, 7-5. The sympathetic nerves are part of the autonomic nervous system, which controls involuntary body mechanisms.

52. Wexler, supra note 19, at 39. Pressure or compression of nerve roots can be caused by a herniated disc, lumbar-disc disease and abnormality generally, and any displacement of discs or the bony structures of the spine, see Ching & Wexler, supra note 18, at 56, as well as by inflammation of surrounding tissues. Archer & Zinn, supra note 2, at 69.

53. Wexler, supra note 19, at 39.

54. W. Keeton, Biological Science 334, 372 (1967); Rein, supra note 2, at 24-2.

55. Rein, supra note 2, at 24-2; LeRoy, supra note 49, at 2; Pochaczewski, supra note 32, at 389; Ching & Wexler, supra note 18, at 53. Wexler further suggests that the small surface vessels affected by the particular nerve root are put into spasm by the excess stimulation of the irritated nerve. Wexler, supra note 19, at 39. Tichauer speculated that muscle spasm might cause certain "cold patches," but this theory does not seem to have been pursued. Tichauer, supra note 11, at 730. But see C. Wexler, An Overview of Liquid Crystal and Electronic Lumbar, Thoracic, & Cervical Thermography 26 (1981). See also 23 Am. Jur. Proof of Facts 2d 11-12 (1980) (mechanisms of reflex pain are not well defined).

56. Pochaczewski, supra note 32, at 389; Christiansen, supra note 16, at 7-1 to 7-3.

57. Wexler, supra note 19, at 39.

58. See supra note 48.

individual may experience referred pain with abnormal skin temperature at some distance from the source of the dysfunction.\footnote{See \textit{Rein}, \textit{supra} note 2, at 24-1; \textit{see supra} note 41 for a discussion of trigger points and myofascial pain syndrome; \textit{see also} Potanin, Hunt \& Sheffield, \textit{supra} note 16, at 204.}

Because the importance of thermography lies in its ability to objectively pinpoint physiological dysfunction, rather than in revelation of the anatomical source of the underlying problem,\footnote{\textit{Rein} \textit{supra} note 2, at 15-2.} the uncertainty regarding the precise mechanism producing variations in skin temperature does not affect the validity of thermography.

\section*{B. Procedure and Protocol}

1. Test protocol. Those who have sought to establish medical thermography as a diagnostic tool have recognized the importance of standardizing test procedure so as to obtain reproducible results.\footnote{\textit{See} Pochaczevsky, \textit{supra} note 32, at 387-88; Wexler, \textit{supra} note 19, at 37; \textit{Rein}, \textit{supra} note 2, at 17-1 to 17-2; Ching \& Wexler, \textit{supra} note 18, at 53.} Reproducible results are necessary to establish the reliability and accuracy of the technique.\footnote{Actual temperature is less important than stability of temperature. \textit{Rein} \textit{supra} note 2, at 17-1.}

Test procedure is designed to eliminate artifacts. The examination room is temperature controlled and draft-free.\footnote{\textit{Id.} Some thermographers have also forced skin cooling by sponging areas to be imaged with water. \textit{Wexler}, \textit{supra} note 39, at Afterword; Pochaczevsky, \textit{supra} note 32, at 387.} The subject spends 10-20 minutes in this or a similarly-controlled room to allow stabilization of skin temperature, a process called equilibration.\footnote{\textit{Wexler}, \textit{supra} note 39 at 30; Wexler, \textit{supra} note 19, at 37; Pochaczevsky, \textit{supra} note 32, at 388. \textit{See Rein}, \textit{supra} note 2, at 17-1 to 17-2.} The imaging process is repeated three times, with 10-20 minute intervals for re-equilibration. An abnormality that is consistently evidenced over this time period reliably indicates physiological damage.\footnote{\textit{Rein}, \textit{supra} note 2, at 27-1; \textit{Wexler}, \textit{supra} note 39, at Afterword.}

Approved protocol includes taking a predetermined sequence of images within a limited time, with the subject positioned so that corresponding left and right parts of the body are imaged, if not on the same view, as close in time as possible.\footnote{\textit{Id.}} For example, where the subject's history suggests lower back spinal nerve root involvement, a sequence might include views of the lumbar region, buttocks, both thighs, lower legs, ankles and feet. Such a sequence will reveal any spinal abnormalities and related manifestations in the extremities, and
allow side-by-side comparison for symmetry. Each image taken photographically or by videotape should be labelled as to time and date taken and subject.

2. Interpretation. In thermography, the subject is his own norm and control; the colors of the image and the actual skin temperature have no particular significance, nor do color/temperature variations from one area to another, unless the patterns thus formed lack symmetry. Consistent absence of symmetry always has a physiological meaning, whether asymmetrical areas are hyperthermic ("hot spots") or hypothermic ("cold spots"). Interpretation of thermograms is based on comparison of thermographic images of the subject, either of left- and right-side images, or of baseline and subsequent images.

While thermography demonstrates physiological abnormality of function, it does not describe anatomical structure: a thermogram cannot indicate when a problem began, or reveal the anatomical cause of an abnormality. Nor does a thermogram "show" pain. Instead, it provides a basis for diagnosis when interpreted in conjunction with a subject's clinical history and complaints, and sometimes with complementary diagnostic techniques, thereby providing objective evidence of

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67. Pochaczevsky, supra note 32, at 388; Ching & Wexler, supra note 18, at 53. See infra notes 74-80 and accompanying text.

68. Such labelling would allow thermograms to be authenticated in court in the same manner as x-rays. Rein, Proving Soft Tissue Injuries in Court, Belli L.J., Winter 1984, 8, 14-15. But see Frias v. Valle, — Nev. —, 698 P.2d 875, 877 (1985) (thermograms not adequately authenticated when no one with personal knowledge (i.e., the thermographer) testified as to how, when, and in what manner the thermographic sequence was performed, although thermograms were labelled with subject's name; admission was error). Further, exact time and date information is vital to validate any interpretation based on thermograms since, to be reliable, a sequence should be completed as rapidly as possible, and to be significant, findings must appear consistently in more than one sequence. Wexler, supra note 39, at 30. See supra note 65 and accompanying text.

69. Rein, supra note 2, at 32-1; LeRoy, supra note 49, at 1-2; text accompanying notes 6-19.

70. Pochaczevsky, supra note 32, at 388-89. The only exception is an increase in temperature occasionally noted in the dominant arm of very muscular men. Id. at 389. Significant thermographic findings may not always be indicative of current pain or dysfunction; they may show sites of old, healed trauma, Ching & Wexler, supra note 18, at 58, and are sensitive enough to show abnormalities in individuals who suffer only intermittent, "clinically subliminal" pain, Wexler, supra note 19, at 39, or who are asymptomatic. Archer & Zinn, supra note 2, at 69.

71. See supra notes 49 and 50 and accompanying text. "Baseline" thermograms, in most cases, are those taken of patients with clinical complaints before surgery or treatment; these are compared with thermograms taken postoperatively or during and after treatment to monitor the patient's progress. See LeRoy, supra note 49, at 3-5. In the case of the spine, there is a known "normal" pattern of heat emission which provides a baseline comparison. See infra text accompanying note 76.

pain-causing conditions. Depending on the history and subjective complaints presented, the thermographer can expect certain thermographic patterns.

Where spinal nerve root involvement is present or suspected, the thermographer studies images of the spinal area and the extremities. A "normal" spine presents a known thermographic image: a warm stripe overlaying the spine from the neck to the lower lumbar area, widening somewhat in the lower thoracic and upper lumbar area, then tapering and ending at the fourth or fifth lumbar vertebrae; warm oval areas corresponding to the sacroiliac joints slightly below and to either side of the lower end of the spinal warm stripe; and a warm area over the cleft of the buttocks. Nerve root involvement in the lumbo-sacral area, or lower back, usually appears as a hyperthermic area overlaying muscles adjacent to the affected nerve root; in the cervicothoracic, or upper back, nerve root involvement tends to result in hypothermia of adjacent muscle areas. In addition to the spinal findings, the thermographer will look for zones of hypothermia ("cold spots") in the extremities along the dermatomes, areas of skin which are affected by the damaged nerve root. Known, distinctive patterns appear in most cases of spinal nerve root involvement, and such nerve root involvement often accounts for persistent pain after an apparently unrelated back injury.

73. Ching & Wexler, supra note 18, at 56, 58.
74. See supra note 52 and accompanying text.
75. Ching & Wexler, supra note 18, at 53, 58.
77. Pochaczevsky, supra note 32, at 389-90.
78. Id. at 388-89. Occasionally (about ten percent of the time, according to REIN, supra note 2, at 32-2), particularly in the hands and feet, "hot spots," or hyperthermia, along the affected dermatome occurs instead. Pochaczevsky, supra note 32, at 389.
79. See Pochaczevsky, supra note 32, at 393; REIN, supra note 2, at 32-6; but cf. Edeiken, supra note 15, at 791 (cervical spine nerve root involvement may create unclear, badly defined peripheral manifestations in the neck and upper back).
80. See supra note 55 and accompanying text.
For a thermographic finding to be considered significant alone, thermograms must show two areas with a minimum of "1°C difference affecting at least 25% of the surface area of the affected dermatome when compared to the opposite view." Usually this calls for a "hot" or "cold" area on the spine, with a cold area in the extremities.81

Other types of spinal damage, including musculoligamentous spinal injuries and osseous lesion (bony structure abnormalities) without nerve root involvement, seem to cause skin temperature changes in the immediate area of the spine, without changes in the extremities.82 The thermographer will interpret the image in light of the known "normal" spine pattern of heat emissions.83

Local trauma has a local effect and may also show as skin patterns related to the unique anatomy of the site of the injury, such as the areas of referred pain associated with trigger points.84 Certain pathologies, such as vascular diseases and joint abnormalities, will be imaged as particular patterns.85

When interpreting any thermogram, note that thermographic abnormalities may change over time. Generally, the early phases are characterized by hyperthermia, which is often followed by hypothermia as the condition becomes chronic.86

81. Wexler, supra note 25, at 28; Rein, supra note 2, at 32-6; Hendler, Uematesu & Long, supra note 12, at 26-2. Less-than-classical thermographic findings may be significant in individual cases, however. Wexler, supra note 39, at 30. Some commentators have noted that color differences may appear more significant than they are when viewed at the 1.0 level (i.e., where the viewing window of the equipment is set so that each color represents a 1°C difference from its immediate neighbors on the color scale, see supra text accompanying notes 25-28); where two colors meet on the thermogram, the temperature difference may be less than 1°C. If this raises questions as to the significance of the findings, it may be appropriate to lower the viewing level to .5 or even .2. Dudley, Peripheral Nerve Loss Seen by Thermography, 21 J. OF CHIROPRACTIC 63 (1984); see Granelli, supra note 5, at 22.

82. Pochaczevsky, supra note 32, at 390.

83. See supra notes 76-77 and accompanying text. Black and white thermograms are preferred for spinal imaging, as the interpreter is looking for a particular qualitative pattern or its absence (unlike other areas of thermography, where quantative images are vital to the significance of findings, see supra note 81 and accompanying text), and black and white more adequately visualizes the spinal pattern, Wexler, supra note 39 at Addendum, whereas "hot spots" may be very small and often linear. Christiansen, supra note 16, at 7-3.

84. See supra note 41; Rein, supra note 2 at 32-2.

85. See Rein, supra note 2, at 32-2, 32-3; Potanin, Hunt & Sheffield, supra note 16, at 203-04.

86. Hendler, Uematesu & Long, supra note 12, at 26-7; Rein, supra note 2, at 32-3.
III. Validity and Reliability of Thermography

A. Validity

Since the 1960's, when thermography was first used to diagnose lumbar disk disease, the sensitivity and reliability of thermographic equipment has significantly increased, with a proportionate increase in the reliability of the technique. \(^{87}\) Thermography's validity, the procedure's ability to show what it purports to show, has been established through clinical and surgical confirmation of thermographic diagnoses, and by comparisons with the accuracy of accepted diagnostic techniques, particularly myelography and electromyography. \(^{88}\)

In 1967, Edeiken presented a study of 26 patients with surgically proven abnormal lumbar discs; both thermography and myelography were predictive in 80% of the cases. \(^{89}\) In 1976, Raskin reported that, for 38 patients with surgically confirmed abnormal lumbar discs, thermograms were predictive 71% of the time, while myelograms were correct for 88% of the cases. \(^{90}\) By studying thermograms of the lower extremities in conjunction with lumbar thermograms, Wexler has found the thermogram to be an accurate predictor of lumbar abnormality in 92% of 51 cases of lumbar complaints confirmed by objective clinical findings. \(^{91}\) In the same study, reported in 1979, the electromyogram (EMG) demonstrated overall accuracy of 86%. \(^{92}\) In a hospital study of 101 patients who had objective clinical findings of abnormalities of the back and extremities, and 61 patients who underwent both myelograms and thermographic studies of the back and extremities, myelographic and thermographic findings agreed in 84% of the cases. \(^{93}\) Thermography demonstrated a higher correlation with the clinical findings, however, with a 79% positive rate; myelograms were positive in only 62% of the cases. \(^{94}\) Thirty-eight patients had surgery, myelography, and thermography: the overall accuracy of thermography, surgically confirmed, was 95%, while that of myelography, surgically confirmed, was 95%. While that of myelography, surgically confirmed, was 95%, while that of myelography, surgically confirmed, was 95%.

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87. Archer & Zinn, supra note 2, at 69; Edeiken, supra note 15, at 792.
88. See infra text accompanying notes 89-97. Electromyography records muscle activity by means of electrodes inserted into soft tissue; it is used in the diagnosis of peripheral nerve lesions. Myelography, a procedure in which the spine is injected with contrast dye and x-rayed, is used to detect ruptured discs. Goodman, supra note 76, at D-5, D-6.
89. Edeiken, supra note 15, at 792.
90. Raskin, Martinez-Lopez & Sheldon, supra note 17, at 151.
91. Wexler, supra note 19, at 40.
92. Id. See also Wexler, supra note 39, at 34 (findings confirmed in study of 130 patients).
93. Pochaczewsky, supra note 32, at 392.
94. Id.
Thermography was 84%. In another recent study of 100 patients with clinical findings consistent with low back pain, thermography gave positive results in 94% of the cases, while CAT scans yielded positive findings only 64% of the time. Using the relatively primitive technique of painting thermographic liquid crystals directly onto the subjects’ skin, researchers at Brook Army Medical Center found that tenderness to palpation was associated with thermographically shown elevated skin temperatures in 80% of 62 patients hospitalized for low-back pain. In the same study, positive thermographic findings correlated well with radiographic findings. Researchers at John Hopkins Hospital performed thermographic evaluations of 224 patients complaining of chronic pain, who had been diagnosed as having only psychogenic pain with no physical cause. They found that 43 of these individuals (19%) had abnormal thermograms indicating nerve root involvement, previously undiagnosed.

B. Reliability

Test reliability relates to a procedure’s consistency over time, in that the same results are obtained when the test is repeated. Thermographers have addressed potential reliability problems via their concern with establishing and maintaining appropriate test procedure and protocol. Proponents/practitioners of thermography assert that its reliability is sufficiently guaranteed when the recommended procedures are conscientiously followed.

The reliability and overall usefulness of thermography have been questioned, however, and the technique is not accepted by all members
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of the medical profession. Some of the resistance is probably due to a measure of conservatism and to the newness of thermographic applications in soft-tissue injuries. Specific criticisms include the thinness of the data base in this area; few statistical studies exist. The relative scarcity of trained and experienced thermographers is another problem. The failure, as yet, to establish "normal" thermographic patterns that take into account factors of age, sex, and body weight, sometimes claimed to affect heat patterns, has troubled commentators. One practitioner strikes a cautionary note:

[Thermography] can show the immediate influence of sympathetic activity on vascular flow in various conditions, but it does not declare the culprit. Although it is an invaluable other "eye," it is no substitute brain and must be interpreted in the context with clinical examination . . . . The thermogram does not displace the skilled clinician, and our ability to integrate this new information is too undeveloped to overstate its value uncritically.

IV. ADMISSIBILITY OF "NOVEL" SCIENTIFIC EVIDENCE: THE FRYE STANDARD

A. The Frye Standard

In 1923, a defendant convicted of murder appealed to the District of Columbia Court of Appeals, alleging as error the trial court's refusal to admit expert testimony on the results of a "deception test," a

104. See Granelli, supra note 5, at 22, col. 2 ("Test is premature"). One proponent suggests that the resistance to thermography is related to an over-reliance on instrumentation and on "hard" signs of trauma, such as gross tendon reflex changes and atrophy, that "occur far along the pathologic path," in a system of medical values that disfavors manipulative clinical techniques as too "subjective." Goodley, supra note 42, at 1004.


107. Granelli, supra note 5, at 23, col. 1-2; See Crawford v. Shivashakar, 474 So. 2d 873, 876 n.4 (Fla. Dist. Ct. App. 1985), where the dubious qualifications of the expert witness were among the several reasons for upholding the exclusion of thermographic evidence.


109. Henahan, supra note 106, at 3302. Attempts to establish a statistically "normal" temperature may underlay the lukewarm findings of one study which concluded that thermography was of little value in the early diagnosis of a degenerative condition of the sacro-iliac, although it might be helpful in the serial assessment of the condition in individual patients. Grennan and Caygill, supra note 108, at 82, 87.

110. Goodley, supra note 42, at 1003-04.

111. Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).
forerunner of the modern polygraph,\textsuperscript{112} administered to the defendant. The court of appeals affirmed,\textsuperscript{113} noting, as virtually the entirety of its opinion, that "while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs."\textsuperscript{114}

This decision, with its enunciation of a "general acceptance" standard, imposed a special burden on the admissibility of so-called scientific evidence in the form of an absolute rule. Under \textit{Frye}, the proponent of evidence obtained by means of a recent scientific or technical theory, technique, or device must demonstrate that the source is generally accepted by the relevant scientific community in addition to proving its relevance.\textsuperscript{115}

\textit{Frye} has been criticised often and ably.\textsuperscript{116} The original opinion gives no authority, purpose, or definitions for the standard, leaving it for courts which apply the general acceptance test to give some definition to its parameters.\textsuperscript{117} Perhaps as a result, the test has been applied selectively.\textsuperscript{118} Courts have wrestled individually not only with the question of when, but of how to apply the standard; identifying the appropriate field; determining whether the underlying principle and technique have been "generally accepted" by members of that field; deciding what must be accepted (i.e., the underlying principle, the technique applying the principle, or both); and determining what types of proof establish acceptance.\textsuperscript{119} Not surprisingly, these problems have been variously resolved.\textsuperscript{120} Moreover, critics have pointed out that the general acceptance standard may exclude reliable and relevant

\begin{itemize}
\item \textsuperscript{112} Giannelli, \textit{supra} note 1, at 1204 n.41.
\item \textsuperscript{113} \textit{Frye}, 293 F. 1013, 1014.
\item \textsuperscript{114} \textit{Id.} at 1014.
\item \textsuperscript{115} \textit{See} Giannelli, \textit{supra} note 1, at 1205.
\item \textsuperscript{116} \textit{See}, e.g., Giannelli, \textit{supra} note 1, at 1206-07 n.59; Imwinkelried, \textit{A New Era in the Evolution of Scientific Evidence — A Primer on Evaluating the Weight of Scientific Evidence}, 23 \textit{WM. & MARY L. REV.} 261, 263 & n.29 (1981).
\item \textsuperscript{117} Giannelli, \textit{supra} note 1, at 1205, 1208; C. McCormick, \textit{Evidence}, § 203, at 605-06 (3d ed. 1984).
\item \textsuperscript{118} McCormick, \textit{supra} note 117, § 203, at 606 n.6; Giannelli, \textit{supra} note 1, at 1219-21; McCormick, \textit{Scientific Evidence: Defining a New Approach to Admissibility}, 67 \textit{IOWA L. REV.} 879, 884 (1982) (test applied consistently only where admissibility of polygraph results at issue; not applied in leading cases admitting expert testimony on fingerprinting, ballistics, intoxication tests, and x-rays) [hereinafter cited as McCormick, \textit{Scientific Evidence}].
\item \textsuperscript{119} \textit{See} Giannelli, \textit{supra} note 1, at 1208-19.
\item \textsuperscript{120} \textit{Id.}.
\end{itemize}
evidence because it seems to require a "cultural lag" between the introduction of a theory or technique and its admissibility.\textsuperscript{121} At the same time, application of the \textit{Frye} standard does not guarantee that unreliable evidence will be excluded.\textsuperscript{122} Concentration on the issue of general acceptance may obscure factors that have more bearing on the reliability and probative value of a technique than does its acceptance in the appropriate field.\textsuperscript{123}

The most adamant position against the \textit{Frye} test is that of McCor- mick, who argues that the traditional standards of relevancy and the need for expertise to assist the factfinder should govern the admissibility of new scientific developments:

General scientific acceptance is a proper condition for taking judicial notice of scientific facts, but it is not a suitable criterion for the admissibility of scientific evidence. Any relevant conclusion supported by a qualified expert witness should be received unless there are distinct reasons for exclusion. These reasons are the familiar ones of prejudicing or misleading the jury or consuming undue amounts of time.\textsuperscript{124}

This approach not only provides adequate protection against invalid and unreliable techniques, McCormick maintains, but properly focuses the court's attention on the actual usefulness of the evidence and issues of jury prejudice and unnecessary expense.\textsuperscript{125}

The general acceptance standard, however, has also garnered support. Fear that juries would be overinfluenced by the aura of "mystic infallibility" that sometimes seems to surround scientific pronouncements has led courts to uphold \textit{Frye} as a means of ensuring that "a minimal reserve of experts exists who can critically examine the valid-

\textsuperscript{121} Giannelli, \textit{supra} note 1, at 1223; United States v. Sample, 378 F. Supp. 44, 53 (E.D. Pa. 1974) (Frye's preclusion of relevant evidence "frustrates the search for truth").

\textsuperscript{122} The most notorious example is the paraffin test, designed to detect whether recent firing of a firearm had left a residue on the user's hand. Although the test was widely used by law enforcement agencies, results of the first comprehensive evaluation of the test were not published until 1967. The study found the paraffin test unreliable. At that time, paraffin test evidence had been admitted under \textit{Frye} for 30 years. Giannelli, \textit{supra} note 1, at 1224-25.

\textsuperscript{123} For example, in the case of the paraffin test for gunshot residues, \textit{see supra} note 122, the problem was nonspecificity; many common substances gave positive results, as did gunshot residues. \textit{Id.} at 1226-27. \textit{See also} Strong, \textit{Questions Affecting the Admissibility of Scientific Evidence}, 1970 U. Ill. L.F. 1, 14 (1970).

\textsuperscript{124} McCormick, \textit{supra} note 117, \textsection 203, at 608 (citations omitted).

\textsuperscript{125} \textit{Id.} at 608-09. McCormick's approach would not, however, completely disregard the acceptance question; "general scientific opinion of both underlying principles and particular applications" could be considered as a factor in evaluating the worth of the evidence offered. \textit{Id.} at 609.
ity of a scientific determination in a particular case." The general acceptance standard has also been deemed necessary protection against protracted "battles of experts," which create confusion and divert time and resources to collateral issues. Critics have pointed out, however, that these concerns can be addressed within the usual rules of evidence, as can the ultimate purpose of the Frye rule — "the prevention of the introduction into evidence of specious and unfounded scientific principles or conclusions based upon such principles." One commentator concluded that the principle justification for the general acceptance standard is that it establishes a method for ensuring the reliability of scientific evidence that assures that those most qualified to assess the validity of a scientific method will have a determinative voice.

Despite the apparent weaknesses and extensive criticism of the general acceptance standard, it has dominated the admissibility of scientific evidence since its introduction. The litigant planning to offer evidence, such as thermograms, to which the Frye test may apply must be prepared to deal with the rule as it has been construed in the litigant's jurisdiction.

There has been some support for the position that Frye (or some other enhanced burden on admissibility) appropriately applies in the criminal context, but that it should not or does not apply in civil litigation. In fact, however, although Frye is more often cited in criminal cases, it has been applied without comment in civil cases.

126. United States v. Addison, 498 F.2d 741, 744 (D.C. Cir. 1974). But see Giannelli, supra note 1, at 1207, nn.60 & 65; McCormick, supra note 117, § 203, at 609 (not all scientific evidence carries with it an aura of infallibility). One commentator suggests that such dangers are especially likely where the evidence was produced with the aid of a mechanical device or "scientific paraphernalia." Strong, supra note 123, at 13.


128. Strong, supra note 123, at 14; See Giannelli, supra note 1, at 1207.


130. Giannelli, supra note 1, at 1205.

131. 1 D. LOUISELL & C. MUELLER, FEDERAL EVIDENCE, § 107, at 853 (1977); Giannelli, supra note 1, at 1246, 1248.

B. Current Status of the General Acceptance Standard

The present status of Frye is unclear. The essential vagueness of the test and the weight of criticism directed at it have caused the standard to be developed differently, modified, and applied selectively in different courts.\textsuperscript{133} The effect of the adoption of the Federal Rules of Evidence in 1975, and the Federal Rules' effect on numerous states' rules,\textsuperscript{134} is uncertain. At least one commentator believes that the cumulative effect of Federal Rules 401 and 403\textsuperscript{135} is to abolish Frye.\textsuperscript{136} Another suggests that Frye is to some extent subsumed under Rules 702\textsuperscript{137} and 703,\textsuperscript{138} which govern the admission of expert opinion testimony.\textsuperscript{139} It is argued that because a judge will rarely be familiar with the scientific technique in question, he will have to base a Rule 703 judgment on evidence that other experts would rely on the same facts in a non-litigation context, a kind of general acceptance standard.\textsuperscript{140} Under this formulation, the Frye test would seem to have no independent existence in jurisdictions where the Federal Rules are in effect.

On the other hand, nothing in the Federal Rules, their history, or the advisory committee comments demonstrates an intention to repu-
The Rules were not intended to be a comprehensive codification; some evidentiary rules are not covered, while others are treated only generally. Since *Frye* was the established rule and it was not expressly repudiated, arguably the general acceptance standard still governs.

Certainly, although a few state courts have taken the position that the Federal Rules of Evidence overruled *Frye*, the federal courts of appeals appear unwilling to abandon the general acceptance standard entirely, either on the basis of the rules or on account of critical indictments of the standard. Federal appellate court decisions of the last ten years, like those of a number of state courts, have tended to modify *Frye* without rejecting it outright.

For example, some commentators have concluded that *United States v. Williams* rejected the *Frye* test in favor of a relevancy approach in the course of its decision to admit spectrographic voice identification evidence. In fact, the Second Circuit only limited the applicability of the general acceptance standard. The court cited McCormick's theory that *Frye* is a proper condition for taking judicial notice of scientific facts, but not for the admissibility of evidence, adding that a distinction must be made "between founding broad legal principles on current scientific 'truths' . . . and admitting particular scientific evidence as probative of an element of a crime." It can be

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141. McCormick, *Scientific Evidence*, supra note 118, at 888; Giannelli, * supra* note 1, at 1229 (Rules are silent as to whether general acceptance standard is superseded).
149. 583 F.2d at 1198 n.7.
inferred that, unlike McCormick, the Second Circuit would find Frye appropriate where novel scientific evidence was offered in support of a "broad legal principle."150 Although the court then applied a Rule 401/403151 relevancy balancing approach to the admissibility issue,152 in the course of its deliberations it considered the acceptance of spectrography’s underlying principles and of the device used to produce spectrograms by technical and legal commentators and by courts,153 all factors in a general acceptance analysis.154 A certain degree of acceptance in the scientific community was recognized as necessary to the finding of reliability that must precede admission.155 Thus Frye, although limited and modified, is still present in Williams.156

Similarly, Coppolino v. State157 is a decision by a state’s highest court that has been widely hailed as rejecting the general acceptance standard.158 Coppolino upheld the admissibility of tests for the detection of a certain poison which were specially developed for the prosecution in that case. The court of appeals acknowledged that it was bound by the Frye standard, but found no abuse of the trial court’s discretion in admitting the test results and conclusion therefrom.159 This result may carry the concept of discretion beyond its outermost limits;160 it is perhaps better explained as one of several cases admit-

150. As examples of instances where courts established broad legal principles on then-current scientific theories, the opinion cites two cases. 583 F.2d at 1198 n.7. The first of these, Buck v. Bell, 274 U.S. 200 (1927), upheld a state statute allowing sterilization of "mentally defective" individuals on the basis of the "fact" that "heredity is important in the transmission of insanity [and] imbecility." Buck, 274 U.S. at 206. The more modern case cited is Brown v. Board of Education, 374 U.S. 483 (1954), where the holding that public school segregation on the basis of race adversely affects the "hearts and minds" of those segregated was bolstered by reference to "modern [psychological] authority." Brown, 347 U.S. at 494. The court specifically cited studies of the psychological and developmental effects of discrimination and segregation on black children. Id. at 494 n.11.

151. FED. R. EVID. 401,403.

152. Williams, 583 F.2d at 1198-1200.

153. Id. at 1196-97 nn.3, 6.

154. See infra notes 257-59 and accompanying text.

155. Williams, 583 F.2d at 1198. See Note, supra note 139, at 786-87.

156. Note that a more recent Connecticut superior court case held a human leukocyte antigen (HLA) test admissible in a civil paternity suit, stating that the test satisfies the Frye standard as adopted by the Second Circuit in Williams, "which held that there must be a preliminary showing that scientific evidence is sufficiently established to have gained general acceptance in its field." Miller v. Miller, 40 Conn. Supp. 66, 69, 481 A.2d 428, 429-30 (Conn. Super. Ct. 1984).


158. See, e.g., I D. LOUISELL & C. MUELLER, supra note 131, § 105, at 824-25; McCormick, Scientific Evidence, supra note 118, at 889.

159. Coppolino, 223 So. 2d at 70-71.

ting evidence derived from tests specifically developed to explore a given problem without applying Frye.\textsuperscript{161}

Commentators cite a number of state court cases allegedly rejecting the general acceptance standard.\textsuperscript{162} In the majority of these cases, however, the refusal to apply Frye extends only to evidence derived from the particular scientific principle, technique, device, or result offered in that case.\textsuperscript{163} Furthermore, state courts that rejected the Frye standard have usually done so on trial records containing persuasive evidence of the validity and reliability of the principles and techniques involved.\textsuperscript{164} Such cases offer no guarantees that the Frye test will not be applied in another context.\textsuperscript{165} It appears that only those jurisdictions that categorically reject Frye as incompatible with the Federal Rules of Evidence\textsuperscript{166} should consistently refuse to require general acceptance as a foundation.

Although very few courts have abrogated Frye in toto, a great number have modified the standard. Perhaps the least radical modification is the substitution of a requirement of “substantial acceptance” for general acceptance in the relevant scientific community.\textsuperscript{167}

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\textsuperscript{161} I D. LOUISELL & C. MUELLER, supra note 131, \S 105, at 824-25. This exception to the Frye test was proposed by A. MOENSSENS, R. MOSES & F. INBAU, SCIENTIFIC EVIDENCE IN CRIMINAL CASES \S 1.03 (1973). See also Phillips ex rel. Utah State Dept. of Social Servs. v. Jackson, 615 P.2d 1228, 1234 (Utah 1980) (scientific test designed specifically for purpose of a lawsuit admissible with sufficient proof of reliability). Cf. Ellis v. International Playtex, Inc., 745 F.2d 292, 303 (4th Cir. 1984) (questions re: methodology of government studies of toxic shock syndrome went to weight, not admissibility, of evidence); Ex parte Dolvin, 391 So. 2d 677, 679-80 (Ala. 1980) (comparison of remains with photograph of alleged victim not subject to Frye); Ibn-Tamas v. United States, 407 A.2d 626, 638 (D.C. App. 1979) (only methodology used in study of battered women must meet Frye standard); Commonwealth v. Devlin, 346 Mass. 266, 191 N.E.2d 479 (1963) (expert’s identification of human remains claimed to be those of murder victim by comparison of ante mortem and post mortem x-rays was not subject to general acceptance standard, where conclusion was based on empirical analysis and expert was one of three or four people in the country with expertise in area).

\textsuperscript{162} See MCCORMICK, supra note 117, \S 203, at 606-07; McCormick, Scientific Evidence, supra note 118, at 897-901.

\textsuperscript{163} E.g., State v. Catanese, 368 So. 2d 975, 980 (La. 1979) (standard is “an unjustifiable obstacle to the admission of polygraph test results” (emphasis added)); State v. Williams, 4 Ohio St.3d 53, 58-59, 446 N.E.2d 444, 447-48 (1983) (spectrogram need not meet Frye standard to be admissible (emphasis added)).

\textsuperscript{164} McCormick, Scientific Evidence, supra note 118, at 901.

\textsuperscript{165} See, e.g., People v. Marx, 54 Cal. App. 3d 100, 126 Cal. Rptr. 350 (1975) (where bitemark evidence offered, issue of technique’s acceptance goes only to weight, not admissibility, of evidence); People v. Shirley, 31 Cal. 3d 18, 641 P.2d 775, 181 Cal. Rptr. 243, cert. denied, 459 U.S. 860 (1982) (hypnotically enhanced testimony excluded under Frye standard).

\textsuperscript{166} See supra note 144.

\textsuperscript{167} United States v. Gould, 741 F.2d 45, 48-49 (4th Cir. 1984); United States v.
test remains as a foundational requirement bearing on admissibility, but is less stringent than the Frye standard. The substantial acceptance standard calls for "some degree of proven acceptance within the appropriate discipline of the 'generalized proposition that constitutes the major premise of the relevance syllogism,' . . . and to this extent it retains the essential feature of the Frye test." 169

Another formulation equates general acceptance with the reliability of the scientific principle or technique from which the evidence is derived. 170 The rationale underlying this approach appears to be that only scientific basis yielding uniform, reliable results are of value to the truthseeking function. 171 The standards are not synonymous; a technique that is "reliable, or sufficiently accurate" need not be generally accepted. 172 The standard is also a long step away from Frye in

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168. United States v. Gould, 741 F.2d 45, 49 n.2 (4th Cir. 1984). Cf. United States v. Baller, 519 F.2d 463 (4th Cir.), cert. denied, 423 U.S. 1019 (1975). The Baller decision stated that "absolute certainty of result or unanimity of scientific opinion is not required for admissibility," holding that spectrographic evidence could be admitted so long as it satisfied a Rule 401/403 balancing analysis, as any other expert testimony. Id. at 466. The Gould court was confronted with an offer of evidence of a pathological gambling disorder as an insanity defense. It held that a relevancy analysis, treating the validity of new scientific techniques as going to the weight of the evidence, to be decided by factfinders, "may be acceptable practice" where admission "involves no more than the consideration of an additional item of evidence in a chain of proof." However, "it is not acceptable where acceptance of the general hypothesis is tantamount to exculpation from otherwise proven guilt." Gould, 741 F.2d at 49 n.2. This concern with the admission of evidence which seems to sweep so broadly that it somehow bypasses the jury's function and dictates the decision on ultimate issues appears to underlay many decisions mandating application of the Frye standard to polygraph results. See, e.g., Commonwealth v. Vitello, 376 Mass. 426, 445, 381 N.E.2d 582, 593 (1978).

169. Gould, 741 F.2d at 49 n.2 (citation omitted).


173. Lipton, The Results of Scientific Techniques as Evidence in Federal Courts: Evolution of the Frye v. United States Standard in the Period 1969-1977, 8 ENVTL. L. 769, 774 (1978). By the same token, the implicit assumption of Frye — that a technique will undergo rigorous testing, sufficient to establish its validity, before it is accepted by the community — is not necessarily true. See discussion of the paraffin test, supra notes 122 & 123 and accompanying text. See Giannelli, supra note 1, at 1225; see also D'Arc v. D'Arc,
that the general acceptance test requires the court to evaluate only the
degree to which members of the relevant scientific community have
found a principle or technique to be useful and reliable; the reliability
standard moves that judgment into court, where, with the aid of ex­
erts, judges make the reliability determination that Frye attempted to
place in the scientific community.

A third modification of the Frye test treats general acceptance as
one factor among the considerations determining admissibility. Some
cases, including United States v. Williams, designate a degree of ac­
ceptance as an element of the reliability of a scientific technique; relia­

tibility is then incorporated into a probativeness/prejudice analysis to
determine admissibility. These cases are not uniform in their treat­
ment of Frye. In Williams, the standard is subtly reincorporated after
its apparent rejection by the Second Circuit's conclusion that "a tech­
nique unable to garner any support, or only miniscule support, within
the scientific community would be found unreliable by a court," and
by the inclusion of "the existence and maintenance of standards"
governing the use of the technique by professional organizations as
one indicator of reliability. Williams lists five indicia of reliabil­
ity, but indicates that not all must be present in every case as a
prerequisite to admissibility. The Third Circuit in a recent deci­
sion endorsed a modified Frye test more directly as "neither a neces­
sary nor a sufficient condition for admissibility; it is, however, one
factor that a district court normally should consider in deciding
whether to admit evidence based upon [a novel scientific] tech­
nique." The evaluation of the technique's acceptance in the field is
part of a determination of the evidence's reliability, and reliability is
part of a traditional balancing analysis. Acceptance may be the de­

157 N.J. Super. 553, 385 A.2d 278 (1978) (general acceptance and reliability are distinct
standards; evidence satisfying either is admissible).
174. 583 F.2d 1194, discussed supra text accompanying notes 145-49.
175. Id. at 1198. See also United States v. Downing, 753 F.2d 1224,1237-41 (3d Cir.
1985); United States v. Brown, 557 F.2d 541, 556 (6th Cir. 1977) (citing United States v.
Amaral, 488 F.2d 1148, 1152 (9th Cir. 1973)).
176. Williams, 583 F.2d at 1198.
177. Id.
178. Id. at 1198-99.
179. Id. at 1200 n.12.
181. Id. at 1237.
182. Id. at 1238-39.
183. Id. at 1237 (admissibility determined by preliminary inquiry concerning: (1)
reliability of the technique, (2) possibility of confusing or misleading the jury, and (3)
relevance).
cise factor in establishing the reliability of the evidence.\(^\text{184}\) An even stronger position has been taken in the Sixth and Ninth Circuits, where “conformity to a generally accepted explanatory theory” is one of four mandatory criteria for the admission of expert testimony.\(^\text{185}\)

The strictest adherence to a pre-Federal Rules of Evidence Frye standard is that of the circuit that originated the test. Without conducting its own analysis of the accuracy of spectrographic voice identification evidence, the District of Columbia circuit held it was wrongly admitted when one expert witness testified that the technique was inaccurate.\(^\text{186}\) General acceptance, required for admission of “new methods of scientific investigation,”\(^\text{187}\) was held to require virtually unanimous support by members of the relevant scientific community.\(^\text{188}\) A similar “nose count” led a District of Columbia trial court to exclude polygraph evidence offered in a libel case.\(^\text{189}\)

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\(^{184}\) Id. at 1238-39. The court held, however, that where a technique has no established “track record,” reliability may be otherwise established. Id. (citing Coppolino v. State, 223 So. 2d 68 (Fla. Dist. Ct. App. 1968), appeal dismissed mem., 234 So. 2d 120 (Fla. 1969), cert. denied, 399 U.S. 927 (1970)).

\(^{185}\) United States v. Brown, 557 F.2d 511, 556 (6th Cir. 1977) (holding evidence of hair comparisons derived from ion microprobing analysis inadmissible for failure to meet general acceptance threshold requirement) (citing United States v. Amaral, 488 F.2d 1148, 1152 (9th Cir. 1973)). The remaining factors are: qualified expert, proper subject, and probative value compared to prejudicial effect. Id. at 556-57. See also United States v. Smith, 736 F.2d 1103, 1106-07 (6th Cir. 1984) (such testimony may now “be said to conform to a generally accepted explanatory theory”), cert. denied, 105 S. Ct. 213 (1984). Cf. United States v. Franks, 511 F.2d 25, 33 n.12 (6th Cir. 1975) (holding general acceptance synonymous with reliability), cert. denied, 422 U.S. 1042 (1975).

\(^{186}\) United States v. Addison, 498 F.2d 741, 745 (D.C. Cir. 1974).

\(^{187}\) Id. at 743.

\(^{188}\) Id. at 744-45. The court counted one expert who testified, one major published study, and two articles supporting the reliability and acceptance of the technique, as against one testifying expert who strongly opposed the technique, and one article whose authors were “dubious, or at least unconvinced” of the reliability of the spectrographic analysis. Id. See Ibn-Tamas v. United States, 407 A.2d 626, 638 (D.C. App. 1979) (Frye applies only to “scientific methodology,” not to particular results based thereon). The conservative values of Addison were cited with approval in People v. Kelly, 17 Cal. 3d 24, 31, 549 P.2d 1240, 1244, 130 Cal. Rptr. 144, 148 (1976) and Reed v. State, 283 Md. 374, 385-87, 391 A.2d 364, 370 (1978), both of which also held spectrographic evidence admitted erroneously. But see People v. McDonald, 36 Crim. L. Rep. (BNA) 2201, 2202 (Cal. Dec. 19, 1984) (Frye not applicable to evidence regarding perception of eyewitnesses); People v. Marx, 54 Cal. App. 3d 100, 110, 126 Cal. Rptr. 350, 355-56 (1975) (general acceptance goes to weight, not admissibility, of bite mark evidence, where evidence is based on hypothesis that is demonstrable in court).

\(^{189}\) Dowd v. Calabrese, 585 F. Supp. 430, 431-32 (D. D. C. 1984) (survey of scientists in field showing that 61% consider technique a useful diagnostic tool fails to meet Frye requirements).
V. MEETING THE FRYE STANDARD: THERMOGRAMS AS EVIDENCE IN MASSACHUSETTS COURTS

A. The General Acceptance Standard in Massachusetts

The foregoing survey demonstrates both the variety and the tenacity of the general acceptance standard. The litigant with thermographic evidence to offer at trial must be prepared with an offer of proof that will satisfy the court that the evidence meets the Frye test as construed in that jurisdiction, or alternatively, that Frye is inapplicable. Taking Massachusetts as a paradigm, this article will consider the various factors involved in the admission of thermograms in a civil suit.190

Massachusetts' Supreme Judicial Court adopted the Frye standard when first confronted with the question of the admissibility of polygraph results offered by the defendant in a criminal proceeding.191 The standard was invoked in upholding the exclusion of the test results on the ground that scientists and "other authorities" considering the polygraph had expressed grave doubts as to the reliability of both the basic premises and the techniques employed in administering the "lie detector" test.192 Later decisions, continuing to apply a general acceptance standard, held polygraph results admissible at the trial judge's discretion where the defendant stipulates in advance to their admissibility,193 and then only for the limited purpose of impeaching or corroborating the defendant's testimony.194

Writing for the court in Commonwealth v. Vitello,195 Justice Liacos stated that the Frye standard as adopted in Massachusetts addresses "practical concerns and policy considerations" raised by expert testimony based on newly developed scientific knowledge.196 In the case of polygraph evidence, these concerns are confusion and prej-

190. The admissibility of thermographic evidence would be a matter of first impression in Massachusetts.
192. Id. at 268-69, 191 N.E.2d at 480. At the same time, the court noted that other novel scientific evidence, including blood tests excluding paternity, blood alcohol content tests, fingerprint and ballistic evidence, had been admitted in Massachusetts without any specific application of Frye upon a showing of "substantial authority establishing scientific reliability." Id. at 269-70, 191 N.E.2d at 481.
196. Id. at 441-47, 381 N.E.2d at 591-96.
udice of the jury, intrusion into the jury's function, and undue consumption of time and trial resources. In this, the test as applied "is not so far removed... from the approach espoused by McCormick." The court's primary evidentiary concern, however, was with the reliability of the technique about which there were still "substantial doubts." Frye appears to have been selected to justify the exclusion of evidence whose reliability is suspect.

In Commonwealth v. Neal, two challenges to a conviction of driving under the influence of alcohol were defeated through the application of Frye. The defendant claimed that his constitutional right to any exculpatory evidence in the Commonwealth's possession required police to preserve the ampules used in his breathalyzer test for retesting by his own expert. The court held that, because the retesting process had not been generally accepted and retest evidence would therefore not be admissible, it could not constitute exculpatory evidence and no constitutional right was triggered. The defendant then excepted to the admission of blood alcohol content evidence based on the breathalyzer test, offering expert testimony that the device used was not reliable because it was susceptible to radio frequency interference. Because breathalyzer results had been deemed generally accepted, the court held that one expert's opinion was not sufficient to require exclusion of the evidence.

In an opinion dealing with the Frye standard in a civil context, the Supreme Judicial Court indicated that evidence derived from computer-simulated accident reconstruction is subject to the general acceptance test. The court did not deny the intrinsic reliability of computer calculations per se, but indicated concern with "the accuracy and completeness of the initial data and equations which are used as ingredients of the computer program," particularly in the face of disagreement among authorities as to the reliability of computer

197. Id.
198. Id. at 443 n.17, 381 N.E.2d at 592 n.17.
199. Id. at 441-42, 381 N.E.2d at 591-92.
201. Id. at 6, 464 N.E.2d at 1361.
202. Id. at 12-13, 464 N.E.2d at 1364-65.
203. Id. at 16-17, 464 N.E.2d at 1366-67.
204. Id. at 17-18, 464 N.E.2d at 1367-68. The court did hold that the challenge was sufficient to require admission of test results to be conditioned on a foundation showing that the machine used was not so susceptible to interference as to create a "significant risk" of an inaccurate result. Id. at 19, 464 N.E.2d at 1368.
simulation.\textsuperscript{206}

The Massachusetts court has also carved out two interesting exceptions to its application of the \textit{Frye} test. In \textit{Commonwealth v. Devlin},\textsuperscript{207} the court held the general acceptance standard did not apply to an expert's identification of remains, claimed by the prosecution to be those of the murder victim, by means of comparison of antemortem and postmortem x-rays.\textsuperscript{208} The identification was based on the expert's opinion, derived empirically from his comparisons of thousands of x-rays, that no two adults have identical bone structures.\textsuperscript{209} The expert testified that he was one of three or four persons qualified to make such identifications, that he had identified unknown human remains by this method before, but that neither he nor anyone else had ever testified to such an identification.\textsuperscript{210}

Had \textit{Frye} been applied, it would almost certainly have acted to exclude this evidence. There was no showing of general acceptance (it is by no means clear what the relevant field would be, in any case), no demonstration of the technique's reliability, and no "track record." Instead, the court held that the evidence was the expert's "medical opinion" rather than the product of a scientific theory, and therefore not subject to \textit{Frye}.\textsuperscript{211} In fact, not only did this evidence involve the scientific theory that each adult's bone structure is visibly distinctive, but it depended on a unique application of that theory to identify decomposed remains, whereas the theory had been developed through comparison of x-rays of living bodies. The court seems to have been comfortable with this evidence because the use and reading of x-rays is generally accepted, and because this particular technique was capable of demonstration in court, allowing the jury to make the same visual comparisons as those upon which the expert based his conclusions.\textsuperscript{212} Although the court did not find reliability established according to the \textit{Frye} requirements, the policy considerations enumerated in \textit{Vitello}\textsuperscript{213} were adequately safeguarded.

\textsuperscript{206} Id. at 177-78, 360 N.E.2d at 1067.
\textsuperscript{207} 365 Mass. 149, 310 N.E.2d 353 (1974).
\textsuperscript{208} Id. at 152-55, 310 N.E.2d at 355-57.
\textsuperscript{209} Id. at 153, 310 N.E.2d at 356.
\textsuperscript{210} Id. at 153-54, 310 N.E.2d at 356.
\textsuperscript{211} Id. at 155, 310 N.E.2d at 357.
\textsuperscript{212} Id. at 154-55, 310 N.E.2d at 357. \textit{See also Ex parte Dolvin}, 391 So. 2d 677 (Ala. 1980); People v. Marx, 54 Cal. App. 3d 100, 110, 126 Cal. Rptr. 350, 355-56 (1975) (\textit{Frye} should apply only when evidence relies on hypotheses not capable of demonstration in court).
\textsuperscript{213} 376 Mass. 426, 381 N.E.2d 582; \textit{see supra} text accompanying note 197.
In Commonwealth v. Lykus, the court upheld the admission of spectrographic evidence under the general acceptance standard, despite a substantial degree of criticism of the technique from experts. The court chose to give greater weight to the acceptance of the technique by those experts who had "direct and empirical experience in the field of spectrography." The Frye standard is satisfied, the court held, "if the principle is generally accepted by those who would be expected to be familiar with its use." In Lykus, the relevant experts included scientists familiar with the underlying principles and their application, as well as criminal laboratory personnel. Thus, it is not clear that acceptance only by operators of a scientific device would satisfy the court.

It is apparent that Massachusetts applies Frye widely but selectively. Little assistance is offered by the first circuit, which seems to condition the admissibility of scientific evidence on proof of a methodology "that meets any of the standards of reliability applicable to scientific evidence." Given the possible pitfalls of the general acceptance standard, there are a number of considerations in the admission of thermographic evidence.

The practitioner who plans to introduce thermographic evidence should analyze and prepare the offering in terms of the particular problems that the Frye standard presents, beginning with the question of whether the general acceptance test applies. The suggested analysis below goes on to consider the court's role under Frye; the effect of the standard on the offeror's burden of proof, questions of what must be accepted, and to what degree, as well as how to identify the relevant field. Finally, the means of establishing general acceptance will be discussed. In general terms, the analysis is relevant to any litigant proposing thermographic evidence under Frye. Specifically, the issues have been worked through in terms of Massachusetts law.

215. Id. at 204 n.6, 327 N.E.2d at 678 n.6.
216. Id.
217. Id. at 203, 327 N.E.2d at 678. In support of this formulation, the court cited People v. Williams, 164 Cal. App. 2d Supp. 858, 862, 331 P.2d 251, 254 (Cal. App. Dep't Super. Ct. 1958). In Williams, however, the acceptance of members of the profession who had no familiarity with the technique (the Nalline test for detecting narcotic use) was not required to meet the general acceptance standard. The Lykus decision, in contrast, excluded from the "relevant field" experts in the field of speech who had studied spectrography and considered it unreliable. 367 Mass. at 204 n.6, 327 N.E.2d at 678 n.6. See Giannelli, supra note 1, at 1210.
B. At the Threshold: Is Frye Applicable?

In certain situations, Frye is not applied. The scientific evidence offered may be derived from principles or techniques that are subject to judicial notice, in which case the technique has moved beyond the need for a general acceptance analysis. Thermography, however, is not yet sufficiently well-known to be the subject of judicial notice. It also seems unlikely that thermographic evidence would be exempted from the Frye test on the ground that it represented the kind of unique application of a scientific technique as seen in Coppolino or Devlin. Unlike the evidence admitted in those cases, thermography is capable of the historical evaluation contemplated by Frye.

Nor should the litigant expect that the standard simply will not be applied by the court, despite the fact that Frye has been applied selectively in Massachusetts, as elsewhere. The Supreme Judicial Court has recently reiterated its adherence to Frye, and has made it clear that the test must be met in civil as well as in criminal cases. Thermography is a likely candidate for the application of the Frye standard because it depends upon the reading of a mechanical device.

C. The Role of the Court

While some courts have treated the general acceptance issue as a question of fact for the trial court, subject only to review for abuse of discretion, others view Frye as a matter of law, subject to de novo

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220. Federal Rule of Evidence 201(b) defines judicially noticed facts as those “not subject to reasonable dispute” because generally known in the jurisdiction, or capable of determination through sources of unquestioned accuracy. FED. R. EVID. 201(b). Recognition of certain fairly recent scientific techniques has reached the level of judicial notice. See, e.g., United States v. Fleishman, 684 F.2d 1329, 1337 (9th Cir. 1982) (handwriting analysis); Lipton, supra note 173, at 770 (radar-based measurement of vehicle speed). Cases have suggested that judicial notice may be triggered by admission of evidence based on the same principle or technique in “a significant number of other districts,” United States v. Downing, 753 F.2d 1224, 1241 (3d Cir. 1985), or by acceptance of a technique in scientific and legal publications. Giannelli, supra note 1, at 1217. Such usage is “problematical,” id., and Massachusetts decisions have considered these factors only in making a determination as to acceptance of a scientific technique. See infra notes 286-88 and accompanying text.

221. See supra note 157-61 and accompanying text.

222. See supra note 192.


226. See, e.g., United States v. Fosher, 590 F.2d 381, 382 (1st Cir. 1979); United States v. Williams, 583 F.2d at 1200 n.12; United States v. Franks, 511 F.2d 25, 33 (6th Cir.
review on appeal.\textsuperscript{227} The abuse of discretion standard tends to be associated with cases where distinctions between \textit{Frye} and the relevancy approach are blurred; the cases usually present fairly strenuous modifications of \textit{Frye}.\textsuperscript{228} Since the reliability of a scientific technique will not vary according to the circumstances of each case, deference to the trial judge's discretion on the threshold question of acceptance is not considered appropriate where the \textit{Frye} standard is more strictly construed.\textsuperscript{229}

The Supreme Judicial Court has indicated that Massachusetts courts must treat the general acceptance standard as a mandatory question of law. The standard is "a rule of exclusion, giving general effect to policy considerations . . . [a]s such it is to be distinguished from evidentiary considerations to be applied at the discretion of the judge or fact-finder."\textsuperscript{230} Massachusetts courts confronted with an offer of novel scientific evidence are instructed to conduct a hearing in the absence of the jury to determine if the technique and its proffered results meet the \textit{Frye} standard, and to create a record for review by entering the findings of fact upon which the decision to admit or exclude the evidence were based.\textsuperscript{231}

D.  \textit{Placing the Burden of Proof}

Application of the \textit{Frye} standard affects the burdens of production and persuasion on the issue of admissibility. A relevancy ap-
proach, where probative value is balanced against the likelihood of harm (under the Federal Rules of Evidence, a Rule 401/403 analysis),232 places the burden on the party opposing admission.233 Any relevant evidence is presumptively admissible, and the opponent of such evidence must show its tendency to mislead, prejudice, or confuse the jury.234 Some courts blend the issue of the helpfulness of expert testimony (Federal Rule of Evidence 702)235 into the threshold admissibility analysis, on the ground that helpfulness is somewhat dependent on whether the status of the body of knowledge upon which the expert bases his opinions is such that the opinions can be more than speculative.236 In those instances, the offeror of the evidence bears somewhat more of the burden.237 Where Frye is strictly applied, as in Massachusetts, the proponent of the evidence bears the full burden of proving general acceptance, while his opponent may await completion of such proof before coming forward with his own experts.238

E. What must be “Generally Accepted”?

Under Frye, it is unclear whether the underlying principle, the technique, or both must be generally accepted.239 Case language referring to acceptance of the "procedure," "technology," "technique," or "theory" does not always seem to represent either a conscious choice or a clear delineation.240 One commentator noted that this distinction is less than satisfactory, creating the same type of difficulties in application as did the rule against opinion evidence.241 Where evidence is only meaningful because some general scientific proposition relates the evidence to the issue of the case, relevancy alone requires that the admissibility of the underlying proposition or theory be established.242 Since establishing the underlying principle does not automatically vali-

232. FED. R. EVID. 401, 403.
233. Giannelli, supra note 1, at 1246, 1247; Note, supra note 139, at 785-86 & nn.84-88.
234. See Vitello, 376 Mass. at 443 n.17, 381 N.E.2d at 592 n.17 (citing MCCORMICK, EVIDENCE § 203, at 491 (2d ed. 1972)); Note, supra note 139, at 785.
235. FED. R. EVID. 702.
236. Note, supra note 139, at 782; see supra note 170 and accompanying text.
237. See United States v. Fosher, 590 F.2d 381, 382 (1st Cir. 1979).
239. Giannelli, supra note 1, at 1211-12.
240. Id. See, e.g., Commonwealth v. Fatalo, 346 Mass. at 266, 269, 191 N.E.2d 479, 481 (1963) ("Judicial acceptance of a scientific theory or instrument can occur only when it follows a general acceptance by the community of scientists involved." (emphasis added)).
241. Strong, supra note 123, at 3.
242. Id. at 6.
date a technique purportedly based thereon, the offeror must then go on to prove acceptance of the technique as a separate issue.

There is, however, a possible exception to this scenario which is of particular relevance to thermographic evidence. Where novel scientific evidence involves the application of a new theory, rather than a novel application of an established proposition, the theory can only be validated empirically, not deductively. The successful application of the theory (i.e., the technique) proves the validity of the theory, rather than the application being deduced from a valid theory.

In terms of the Frye test, if the technique is generally accepted, then the theory must be valid although not fully understood or explainable. Thus, proponents of voiceprints [spectrograms] have argued that even though the "why" and "how" of the technique are not fully understood, the technique works and that alone is sufficient validation. Similarly, one commentator has argued: "[T]here does not appear to be general acceptance of a theory to explain all the phenomenon of aspirin. But even though aspirin's theoretical underpinnings may never be elucidated to the satisfaction of the scientific community, the fact is that it works." Where a technique is developed empirically, its foundation is to show that in each instance where the technique was applied, consistent results were obtained. The validity of the underlying theory is inferred from the consistency of the results derived from the technique. Empirical validation has been recognized as a method of establishing the reliability and admissibility of certain techniques, including fingerprinting and firearms identification as well as spectrography.

The Supreme Judicial Court concluded that spectrographic evidence was admissible under Frye on the basis of an extensive series of voice identification experiments. The experiments established that the technique had a "negligible" rate of error (i.e., that results were consistent and the technique reliable). The court was then prepared to acknowledge that the technique was generally accepted, although

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243. See, e.g., Giannelli, supra note 1, at 1212.
244. Id.
246. Id. at 1212 & n.104.
247. Id. at 1213. See also 22 C. Wright & K. Graham, Federal Practice and Procedure § 5169, at 95 (1978) ("It would be rational to rely upon a scientific device to determine deception if experiments proved that it worked, even though there was dispute about why it worked.").
249. Id. at 200-01, 327 N.E.2d at 676-77.
there was some evidence to the contrary. The validity of the underlying theory was not otherwise explored.

This may provide a guideline as to what the proponent of thermographic evidence must show to prove general acceptance, since thermography, like spectrography, is a technique whose underlying principles are not clearly established, but whose reliability, arguably, has been empirically validated. The litigant would therefore be justified in showing the acceptance and reliability of the technique of thermography, without delving into theoretical explanations of the mechanisms causing abnormalities to be reflected in asymmetrical surface heat emissions, an area in which there is disagreement even among those who accept the technique. The litigant should be prepared to offer testimony on the way in which the thermographic apparatus functions, how surface temperature affects the thermographic display, and on the correlation between thermographic results and those of the diagnostic procedures of electromyography, myelography, and clinical diagnosis, all of which are accepted as objective means of verifying physical pain and dysfunction. Such an offer of proof should be sufficient to show that the technique has been empirically validated, and adequately defines the area that must be "generally accepted."

F. Identifying the Relevant Field

Defining the community that must accept a scientific principle or technique can be difficult for purposes of the Frye standard, particularly when the thing is not indigenous to any one clearly defined field. Much of the evidence excluded under Frye was not readily identifiable with any one scientific discipline. Medical thermography has been developed, tested, and used by practitioners in a number of areas. The potential problems presented by this situation are somewhat alle-

\[\text{250. Id. at 204 n.6, 327 N.E.2d at 676-77.}\]
\[\text{251. See supra, notes 51-61 and accompanying text.}\]
\[\text{252. See supra, notes 87-101 and accompanying text.}\]
\[\text{253. See supra, notes 51-60 and accompanying text.}\]
\[\text{254. See supra, notes 20-39, 62-68 and accompanying text.}\]
\[\text{255. See supra, notes 21-22, 32-33 and accompanying text.}\]
\[\text{256. See supra, notes 88-101 and accompanying text.}\]
\[\text{257. See Commonwealth v. Lykus, 367 Mass. 191, 196-97, 200-01, 327 N.E.2d 671, 674, 676-77 (1975) (showing "the nature of the scientific machine involved" and the reliability of the technique).}\]
\[\text{258. Strong, supra note 123, at 12. See also Giannelli, supra note 1, at 1208-09.}\]
\[\text{259. These areas include human medicine, physiology, physical medicine and rehabilitation, chiropractic, neurosurgery, biomechanics, radiology, and orthopedics. REIN, supra note 2, at 2-1 to 2-3; Fay v. Mincey, 454 So. 2d 587, 592 (Fla. App. 1984).}\]
viated for the Massachusetts litigant by the definition of the appropriate field as developed in *Commonwealth v. Lykus*.260 The *Lykus* formulation calls for general acceptance of the technique "by those who would be expected to be familiar with its use" (emphasis added).261 At the voir dire hearing on the admissibility of spectrographic voice identification evidence, the prosecutor in *Lykus* presented the testimony of an academic scientist and researcher in speech science, and also of a state trooper affiliated with a state forensic laboratory's voice identification unit.262 The scientist testified that the technique's reliability had been established empirically,263 while the trooper, who had made the identification ultimately offered in the case,264 was able to testify to the procedures used and the qualifications of the examiners.265 Voir dire evidence also showed that opponents of the technique had only "theoretical" knowledge of its use, and were without "empirical experience."266

With *Lykus* as a model, the litigant should attempt to define the relevant community as those with training and experience in the practice of medical thermography. This group will include chiropractors,267 but will not exclude practitioners in other fields whose knowledge and experience can qualify them as experts on the more technical aspects of the apparatus used and the empirical validation of the technique,268 areas that the trial judge will probably explore at the voir dire.

262. Id. at 195, 327 N.E.2d at 673.
263. Id. at 200-01, 327 N.E.2d at 676-77.
264. Id. at 195, 327 N.E.2d at 673.
265. Id. at 201-02, 327 N.E.2d at 677.
266. Id. at 200, 204-05 n.6, 327 N.E.2d at 676, 678-79 n.6.
267. Thermography is taught at the National College of Chiropractics and is routinely used by chiropractors. Fay v. Mincey, 454 So. 2d 587, 592 (Fla. App. 1984).
268. Chiropractors will probably be considered unqualified to testify in these areas while the technique is still unfamiliar to courts. Note that thermography is taught as an elective and/or continuing education course at a number of medical schools, including Johns Hopkins, Georgetown, George Washington University, University of Oklahoma, State University of New York, Albert Einstein, and Veterans Administration hospitals, and through the American Thermographic Association, the International Thermographic Society, and the National Board of Thermography. Fay v. Mincey, 454 So. 2d 587, 592 (Fla. App. 1984), Procida v. McLaughlin, 195 N.J. Super. 396, 403, 479 A.2d 447, 451 (1984). The practitioners whose studies validating medical thermography are cited supra notes 1-101, Edeiken, Pochaczewsky, and Wexler, inter alia, are medical doctors. The *Lykus* formulation should allow the inclusion of such experts within the relevant scientific community without requiring that all members of the medical professions accept thermography.
G. What Constitutes General Acceptance?

No actual number of those in the field who must accept a technique in order for it to be considered generally accepted has ever been established. Massachusetts has set a liberal, if vague, standard; the Supreme Judicial Court noted that Fatalo and Frye do not require "unanimity of view, only general acceptance; a degree of scientific divergence of view is inevitable." Other cases speak of "substantial authority" and "a consensus of expert opinion which the court can accept as creating a valid basis for expert testimony." Thus the court has reiterated its basic concern with the reliability of novel scientific evidence and with the Frye standard as a safeguard on that concern, rather than with numbers per se.

H. Establishing General Acceptance

The general acceptance of a scientific technique can be shown in three ways. Typically, acceptance is demonstrated through expert testimony. Technical literature and legal precedent, however, can also be useful in establishing reliability and acceptance. Particular problems likely to be encountered in introducing novel scientific techniques via these methods are discussed below.

1. Expert testimony. The offeror of thermographic or other novel scientific evidence should be prepared to demonstrate acceptance and reliability through the testimony of more than one expert. In two cases holding thermographic evidence admissible, the proponents offered at least two experts, one qualified to testify to the acceptance of thermographic principles and overall reliability of the technique, while the second was the medical practitioner who had per-

269. Giannelli, supra note 1, at 1210-11; Strong, supra note 123, at 11.
270. Lykus, 367 Mass. at 204 n.6, 327 N.E.2d at 678 n.6.
272. Vitello, 376 Mass. at 441, 381 N.E.2d at 591 (quoting W. Leach & P. Liacos, Massachusetts Evidence 94 (4th ed. 1967)).
273. See id. But cf. Lykus, 367 Mass. at 199-200 n.3, 204-05 n.6, 327 N.E.2d at 676 n.3, 678-79 n.6 (hint of nose-counting).
274. Note the use of two experts in Lykus, discussed supra notes 260-66 and accompanying text. See Giannelli, supra note 1, at 1215-16; Note, supra note 139, at 785 n.79 ("Even courts that use tests other than Frye have recognized... that a single expert... cannot demonstrate reliability."); United States v. Downing, 753 F.2d 1224, 1240 n.21 (3d Cir. 1985) ("proponent must make more than a prima facie showing (e.g., the testimony of a single qualified expert) that a technique is reliable"). Cf. Neal, 392 Mass. at 18, 464 N.E.2d at 1367 (opinion of one expert that previously admissible evidence has become unreliable does not by itself require exclusion of the evidence).
formed and interpreted the offered thermograms. These experts testified to the use of thermography as a medical diagnostic tool among practitioners, and to its application in the case at hand.

The use of more than one expert is necessary because the operator of the equipment may not be considered qualified to testify to inferences based on test results (here, the inference of the reliability of the technique) or to the technology of the apparatus itself. Requiring more than one expert also appears to be a sop to the idea of proving general acceptance, imposing a "corroboration rule" as protection against having to assess the position of a scientific community on the basis of the opinion of one interested, and possibly biased, witness.

Qualifying experts in thermography presents no unique problems. Where the litigant seeks to introduce the testimony of a chiropractor, he may find a reference to the statute defining the scope of chiropractic medicine useful. The statute encompasses the use of "the x-ray and analytical instruments" in chiropractic examinations. A similar statute was held not only to bring thermography within the ambit of chiropractic and to be a factor in qualifying an otherwise knowledgeable chiropractor to opine on thermographic results, but also to constitute statutory approval of thermography in the diagnosis of lower back injuries.

2. Scientific and legal literature. Courts frequently consider publications in the field, and legal commentary on scientific techniques

276. Fay v. Mincey, 454 So. 2d 587, 590-92 (Fla. App. 1984); Procida v. McLaughlin, 195 N.J. Super. 396, 398-400, 479 A.2d 447, 448-50 (1984). The plaintiff in Procida also presented a third expert who testified to the design and operation of the apparatus used. Procida, 195 N.J. Super. at 398-400, 479 A.2d at 449-50. Cf. Crawford v. Shivashankar, 474 So. 2d at 876 n.4 (mediocre qualifications of the single expert went to "the quality of the proof" and were a factor in finding on appeal that trial judge had not abused discretion in excluding testimony on thermograms). See Ferlise v. Eiler, 202 N.J. Super. 330, 335-36, 495 A.2d 129, 131 (1985), holding the admission of thermograms to be error, where the appeals court complained that the one expert offering testimony had no special training in thermography, while the radiologist who had interpreted the thermograms was not called.


278. See People v. Kelly, 17 Cal. 3d 24, 39, 549 P.2d 1240, 1250, 130 Cal. Rptr. 144, 154 (1976). In Kelly, testimony of the forensics expert who helped to establish the admissibility of spectrographic evidence in Lykus was excluded on the same issue because he was qualified as a technician and law enforcement officer, not a scientist. Id. at 41, 549 P.2d at 1251, 130 Cal. Rptr. at 154-55.

279. Giannelli, supra note 1, at 1215-16.

280. MASS. GEN. LAWS ANN. Ch. 112, § 89 (West 1983).

281. Id.


283. Id. at 595 n.12.
used to produce evidence, in making a determination on general acceptance.\textsuperscript{284} The relevant literature has been regularly used in Massachusetts, both to establish reliability and to indicate the prevailing degree of acceptance of a technique.\textsuperscript{285}

3. Precedent in other jurisdictions. Courts in Massachusetts, as elsewhere, have considered decisions from other courts in determining the admissibility of evidence under \textit{Frye}.\textsuperscript{286} The Massachusetts court seems to take judicial notice of the decisions themselves, considering general acceptance by the courts as well as by scientists.\textsuperscript{287} Since the court is willing to recognize expert opinion as reflected in literature and judicial decisions, the testimony of experts in other cases should also be subject to judicial notice.\textsuperscript{288}

The litigant proposing to introduce thermographic evidence would do well to demonstrate that medical thermography is making its way into the courts. Thermography has been admitted or recognized in a number of cases in jurisdictions including California,\textsuperscript{289} Idaho,\textsuperscript{290} Illinois,\textsuperscript{291} Florida,\textsuperscript{292} Louisiana,\textsuperscript{293} Michigan,\textsuperscript{294} and New

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Jersey,\textsuperscript{295} and Rhode Island.\textsuperscript{296} Thermographic evidence has been admitted in federal courts in criminal prosecutions.\textsuperscript{297} Several courts have cited the failure to use thermography as some evidence of negligence in medical malpractice cases, indicating that those courts recognize the reliability of the technique.\textsuperscript{298}

V. CONCLUSION

Medical thermography is a technique of great potential in personal injury cases. In certain types of injuries, notably lower back damage, whiplash, and nerve root involvement, thermograms may provide the only objective evidence of a paincausing condition. Moreover, thermography may support a claim that an alleged injury is psychosomatic or fraudulent. Thermographic evidence is graphic and dramatic, and allows a jury to become involved and to "see" an injury that would otherwise only be presented verbally.

The litigant, however, must be prepared to meet an enhanced burden on the issue of admissibility. The \textit{Frye} general acceptance standard remains remarkably pervasive in various forms, and may well be applied to the question of the admissibility of thermograms or other novel scientific evidence. Academic arguments as to the propriety and efficiency of the standard, while intriguing, are of limited use to the practitioner who seeks to introduce thermograms at trial in a jurisdiction where the court must, or probably will, apply \textit{Frye}. Careful analysis of the issues that the general acceptance standard presents should


\textsuperscript{296} Monegro v. Sears, Roebuck & Co., No. 81-2158 (R.I. 1985).

\textsuperscript{297} Fleming v. U.S.D.A., 713 F.2d 179, 185, 187 (6th Cir. 1983); Thornton v. U.S.D.A., 715 F.2d 1508, 1510 (11th Cir. 1983). Thermograph tests were used in both cases to corroborate the opinions of examining veterinarians in determining whether a horse had been sored for the purpose of imposing liability.

\textsuperscript{298} Tiernan v. Hernzen, 104 A.D. 2d 645, 480 N.Y.S.2d 24 (1984); Tribou v. Gunn, 410 So. 2d 378 (Miss. 1982); Jones v. Montfoure Hospital, 431 A.2d 920, 924-25 (Pa. 1981); Johnson v. Misericordia Community Hospital, 301 N.W.2d 156, 164 (Wis. 1981).
enable the litigant to prepare to convince the court that thermography is sufficiently reliable to justify its admission.