

# Vapor and Condensation (And Termination of Several Myths)

By LYLE D. HOGAN, RRC, FRCI

**T**HE DEVELOPMENT OF CONDENSATION WITHIN compact roof assemblies fosters a number of problems. Most of these moisture entrapment problems shorten the service life expectancy of the roof which then can be understood in financial terms (an issue sure to attract attention).

Moisture vapor behavior is a rather straightforward concept, yet the misunderstanding of it is so pervasive that it seems to feed on itself. Such misunderstanding leads to unfounded beliefs, such as...

- ▼ "All single ply roofs eventually develop condensation."
- ▼ "Better not fasten the roof on that freezer! There will be condensation on the screws."
- ▼ "Aren't you going to put a vapor barrier in that freezer?"
- ▼ "Adding a recover insulation will make the dew point fall in the insulation."
- ▼ "If you over-roof that building, you will be creating a dew point."
- ▼ "Two sheet membranes lying in contact will form condensation between them."
- ▼ "We put a vapor barrier in everything."

The pundits of such beliefs would do well to secure continuing education in basic heat transfer. For those who are too busy, this article is for you.

## OVER-ROOFING MYTHS DISPELLED

The practice of over-roofing wet materials is considered irresponsible by many accounts (Baxter, 1986). Yet, it would be shortsighted (and disservice to a client) to ignore the potential for some assemblies to experience drying. The "self-drying" concept is probably older than anyone reading this. Its implementation mandates that there be no vapor retarder present in the compact roof assembly and that a relatively permeable substrate is present to permit liberation of moisture downward into the building interior (Griffin, 1982).

Many roofs without a vapor impedance layer will "seasonally" gain some amount of moisture in excess of that perhaps originally present. Figure 1 depicts the drive which induces wetting and dry-

ing as a result of the pressure acting across the roof surface. Periodic accumulation of moisture may be tolerable if the "net" behavior is that of drying or, at least, restoration of the insulation's equilibrium moisture content.

Several compact roof assemblies can experience drying of the insulation. Many will not. Considerable study has centered around this distinction, and time-to-dry calculations have been empirically derived (Lankton, 1991). Although not considered a "compact" assembly, the domain of metal roof retrofit is an example where appreciable drying can be realized (Haddock, 1996). This instance is usually more of an upward drying mode induced by the new vented plenum configuration.

Our industry is rich, however, with examples of over-roof assemblies which soon became wet once fastened over wetted materials. The sins of the old roof are soon visited into the new one. The sun passing repeatedly over entrapped water invites upward migration (through the numerous fastener holes) into the new layer of insulation. Wetting has also been observed with tapered insulation crickets and saddles placed over a membrane where no fastening devices played a role (Canon, 1984).

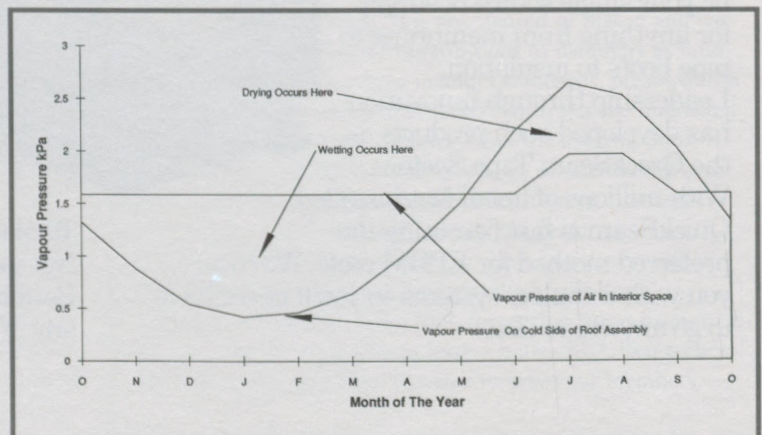


Figure 1: Seasonal variations of vapor pressure drive across an insulated low-slope roof in Toronto. Winter interior condition of 22°C and 60% relative humidity and summer interior condition of 22°C and 70% relative humidity. Figure reprinted from "Corrosion of Structural Steel Deck Under Roof Assemblies with Non-Foam Insulation" (by H. Doshi, V. Stritesky, P. Lanni in Oct. '97 issue of Interface).

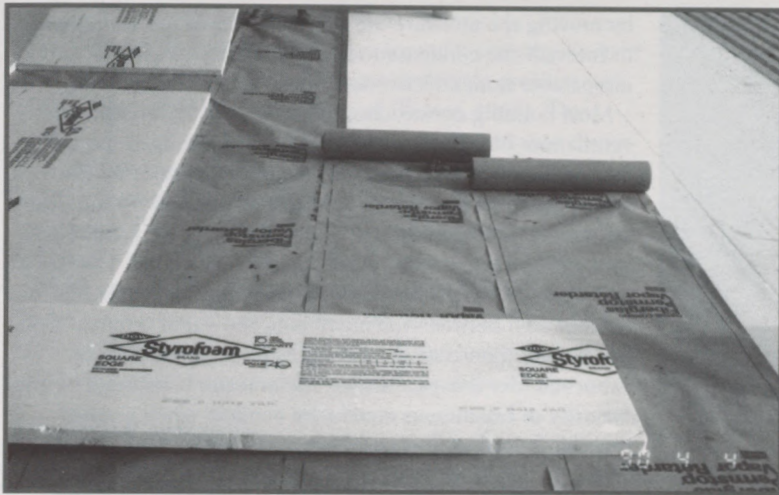


Figure 2: A need for vapor impedance is unrelated to the type of roof covering used.

There is a widely-held misconception that a "dew point problem" is generated by over-roofing where not enough new insulation is incorporated. No such condition can be generated. With 1) dry original insulation present, 2) a continuous old membrane left in place, 3) and a functional new membrane covering installed over 4) dry new insulation, there is no physical way for moisture to form in the new recover insulation layer. The problem is that these four precepts are rarely satisfied in recover instances.

After a recover, if condensation is observed on the deck's underside, the original insulation was inadequate, and the problem existed prior to over-roofing. It may well be that an existing condensation problem was not remedied by the over-roof. Development of condensation, however, is not possible by making the construction warmer by any increment.

If condensation is observed between the two membranes, one of the four earlier stated precepts has been triggered. The fault does not lie with the thickness of the recover insulation.

The dew point temperature will virtually always fall within the stratum of the insulation. This can be demonstrated by plotting a temperature profile across various levels of the assembly. Sizing of insulation is critical, an effort not being dismissed lightly in this paper. All practitioners of roof design should be intimately familiar with the procedure; however, mathematically sizing retrofit insulation (to avoid condensation) is a futile exercise unless the building occupancy (function) has changed. Satisfying the prevailing energy code (thermal) requirements is a far more meaningful effort.

### CONSIDERATION OF VAPOR RETARDERS

Industry consensus regarding vapor impedance layers has matured. The earliest doctrine was, "when in doubt, leave it out." This evolved into "when in doubt, figure it out." Such figuring was accomplished using two parameters put forth by the NRCA. A vapor retarder was advised when both of two parameters were satisfied:

- 1) The mean January temperature prevailing would be 40°F or less, and
- 2) The documented interior relative humidity would be in

excess of 45%.

While still a recognized protocol, broadened observations have led to CRREL (Cold Regions Research and Engineering Laboratory) and ASHRAE (American Society of Heating Refrigeration and Air Conditioning Engineers) methods for determining the actual need for a vapor retarder. Yet none of these recipes recognizes the roof material types used in the assembly. Some have higher moisture tolerance than others (Smith, 1997).

By whatever means a vapor impedance layer is selected, its need is not related to the roof membrane type. A vapor retarder is just as well suited to a single ply assembly (Figure 2) as it is to a conventional bituminous roof system. Analysis for the need (of a vapor retarder) should probably focus more on the deck and insulation type being used, but the membrane type is an unimportant variable for this deter-

mination.

Finally, incorporating a vapor retarder in every roof assembly is intellectually vacant. Reasoning in this manner apparently stems from trying to swaddle the designer in a cloak of safety. However, it can do more harm than good in several instances. As stated earlier, its presence impedes whatever self-drying tendency the assembly may have otherwise enjoyed.

### FREEZER CONSTRUCTION

The directional change in vapor pressure drive is a seasonal phenomenon responsible for moisture content variation in building components. Yet freezers experience a prevailing inward drive, more notable in southern settings where the magnitude of the drive can be seasonally significant, periodically extreme.

There is no vapor retarder in freezer construction. The membrane covering serves that function, and it should be kept as high up in the assembly as possible. Inverted roofing could be configured to work, but most inverted assemblies have the majority of insulation above the membrane. This would be a mistake on freezer construction. As more of the total insulation is placed under the membrane, the profile begins to resemble conventional roofing, discounting the advantage of inverted roofing for this particular setting.

Fastening into freezer decks is considered verboten for fear of condensation. This is largely a fallacy and widely misunderstood. Condensation will surely occur. It occurs on the top surface of the membrane where it is of no more consequence than dewfall from the prior evening. While fastening may not represent the optimum roof configuration, such arrangement is not destined for failure.

Of more interest is the heat transmission experienced from within at the numerous fastening devices. Thermal conductivity by ferrous fasteners has been quantified across both steel and wood roof decks (Burch, et.al., 1987). The mechanically-attached configurations modeled in that work (steel decks) were found to diminish the overall thermal resistance by 3-

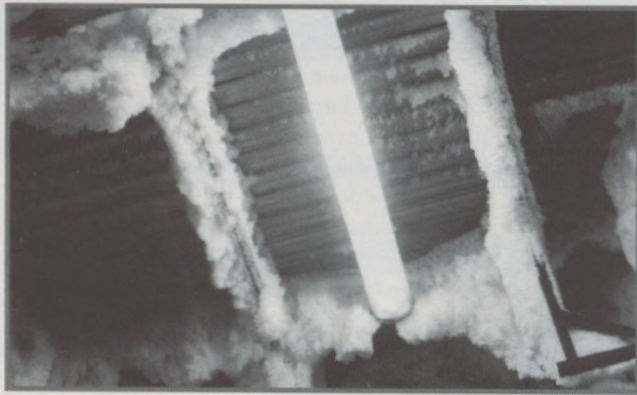


Figure 3: A vapor leak in a freezer is far more calamitous than a roof leak. Nonetheless, the roof membrane serves the function of the vapor retarder in this environment.

8%, varying by the insulation thickness present. Wood deck assemblies generated about half that loss in the model. Plastic stress plates sharply reduced these figures in both instances.

All energy loss is a legitimate consideration when sizing refrigeration hardware. Yet the importance of the thermal bridge at fasteners should be analyzed against the more apparent loss as forklifts continually pass through the partition doors within. Whatever the thermal loss, condensation in freezers (from a fastened roof) is a non-issue.

A one-ply, exposed, black membrane may not be well suited to a freezer environment. There can be long-term moisture gain diffusing into the assembly with certain polymeric membranes (Walters, 1985). Coolers and freezers represent the only instance known to this author where membrane formulation plays a role in "real-life" moisture accumulation scenarios from the top side. Membrane color is the more important aspect since permeance is a function of temperature.

This blunt discussion is not intended to discount the importance of detailing freezer facilities. Because the environment is so extreme, freezer construction is absolutely critical. An incoming air leak is usually far more calamitous than a roof leak (Photo 3), and the roof-to-wall connection is perhaps the most important feature for detailing (Hogan, 1995). But the need for some vapor impedance layer (beyond the roof membrane) has not been demonstrated to this writer.

## THE ATTRIBUTES OF VENTING

Where condensation risk cannot be remedied by making the construction warmer, there is another treatment available. Note that a calculation to determine insulation thickness is a two dimensional study which makes no consideration for the movement of air. The calculation may be flawed by assuming 1) continuity of insulation and 2) steady state behavior (i.e., no change in the conditions being modeled).

As shown in Figure 4, a certain minimum required R-value may emerge from the calculations when, in fact, less would be perfectly functional if the air movement was considered. The great benefit of ventilation is that

by moving the moisture-laden air, less insulation is required to forestall the condensation. In truth, sizing of insulation is inseparable from effectiveness of the ventilation system.

Most building construction could benefit from improved ventilation. But the ventilation discussed here is exclusively that of the plenum or under-deck surface. Venting of the compact roof is a separate (but similarly misunderstood) consideration. Tobiasson has "yet to find a compact membrane roof with problems attributable to a lack of vents" (Tobiasson, 1990). That study reviewed the proprietary "top-side" devices used between the membrane and vapor retarder. Still, it is common practice to provide top-side venting when a vapor retarder is used. Further, the practice is required by the majority of bituminous membrane vendors when a vapor retarder is used in the assembly.

## VAPOR DISPERSION AND MEMBRANE PERMEANCE

The perm rating of polymeric one-ply membranes has been so badly confused that it bears clarification in this article. At least some of the confusion stems from the various ways to express the ability of a thin film to "breathe." Vapor passage through a thin film may be expressed as perms, perm-inches, perm-mils, or grains of water per square foot per hour per inch of mercury (pressure difference across the surface). Any comparison of membrane products must proceed from equivalent units of measurement.

Early sales tactics made claim to drying of wetted insula-

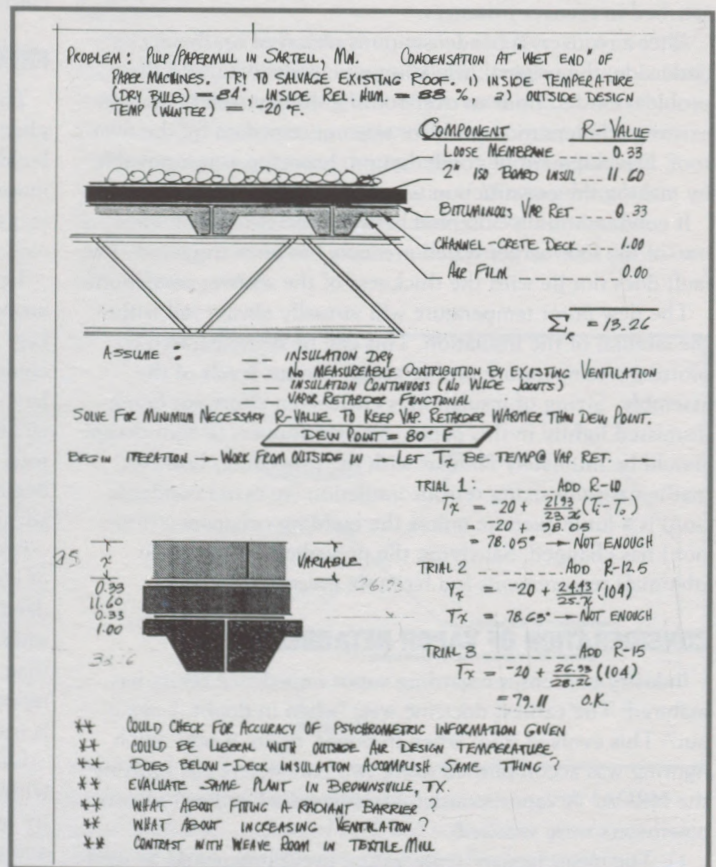


Figure 4: A calculation to size roof insulation may be flawed by failing to consider both 1) the ventilation effectiveness and 2) the discontinuities of the insulation.

tions by overroofing with one of these "permeable" sheet systems. It is true that some membrane formulations may liberate some amount of moisture if adequate underside pressure was present for a sufficiently long period (Potter, 1985). This amount of pressure (required to induce moisture vapor dispersion through a membrane) has not been recorded in our work. Whatever amount of vapor actually diffuses through a continuous sheet membrane is small—somewhere between zero and tiny.

Don't expect the polymeric membrane to induce any drying (through the top) of entrapped water. Moreover, don't blame it for admitting water vapor inward (Figure 5) with the possible exception of the freezer/cooler condition examined above.

## SUMMARY REMARKS

Water may be considered as the universal solvent, eventually compromising almost anything. Its occurrence in compact roof assemblies is an embarrassment at minimum, a disaster more frequently. Entrapped water has provided a number of opportunities for trial lawyers, expert witnesses, and consultants. Convincing testimony can sometimes obscure the truth underlying an event. Yet rich vocabulary regarding diffusion rates, perm ratings, and ventilation ratios does not refute the unalterable physics of moisture vapor behavior.

A roof assembly given to moisture gain from internal drive will behave thusly irrespective of polymeric formulation of the membrane. Any measure of making an assembly warmer (however small in increment) cannot be shown as the culprit of condensation. Ventilation (in the plenum) can be a redeeming practice, salvaging numerous roofs experiencing unwanted moisture gain. This is pivotal in the drying sometimes observed in metal roof retrofit schemes (Figure 6).

Finally, condensation which cannot be demonstrated on ordinary psychrometric curves (Figure 7) cannot be substantiated. Moisture developing in a roof in spite of proper curve interpretation bears out something other than condensation at work. Where the occurrence of condensation cannot be managed by insulation and ventilation, inverted roofing should be considered more frequently.

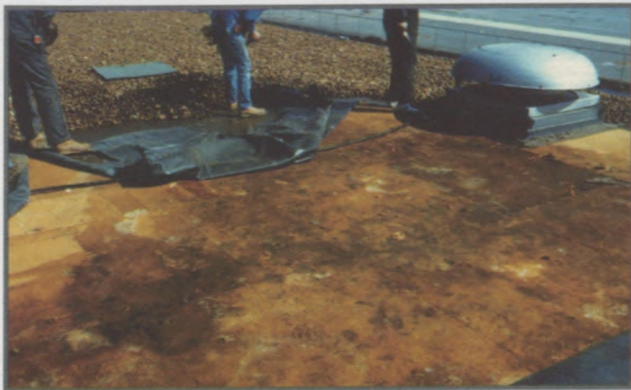


Figure 5: Single ply roof coverings have long been named as the culprit of unexplained moisture gain in compact roofs. Membrane formulation has nothing to do with moisture gain from below. Aside from cooler and freezer construction, the formulation has nothing to do with moisture gain from above.



Figure 6: Retrofit metal roofs have, on occasion, induced drying of old materials left in place. The attributes of plenum ventilation are largely responsible. (Photo courtesy Rob Haddock.)

## REFERENCES

- Baxter, Richard, "1001 Reasons Not to Roof Over Wet Insulation," *Roofing Spec*, August, 1986.
- Burch, Douglas M., Shoback, Paul J., and Cavanaugh, Kevin, "A Heat Transfer Analysis of Metal Fasteners in Low-Slope Roofs," *Roofing Research and Standards Development (ASTM STP 959)*, December, 1987, pg. 10.
- Canon, Richard, "Infiltration of Moisture into Perlite Crickets and Saddles," *Roofer*, October, 1984, pages 18, 20, 22.
- Griffin, C. W., "Vapor Control" chapter, *Manual of Built-up Roof Systems*, McGraw-Hill, 1982, page 108.
- Haddock, Rob, "Don't Tear It Off; Metal Is Different," *Interface*, March, 1996, pg. 15.
- Hogan, L. D., "Designing Roofs to Avoid Air Invasion and Positive Pressure from Within," (proceedings from) *Thermal Performance of the Exterior Envelopes of Buildings VI*, December, 1995, pg. 732.
- Lankton, Lee Ann, "A Method to Determine the Suitability of Recovering an Existing Roof Assembly Considering the Effects of Existing Moisture," (presentation given at RCI annual convention, Colorado Springs, 1991).
- Potter, John, "The Way Ahead for Flat Roofing," (proceedings from the) *Second International Symposium on Roofing Technology*, 1985, pg. 349.
- Smith, Thomas L., "Vapor Retarders: An Overview of New Design Criteria," *Professional Roofing*, October, 1997, pg. 46.
- Tobiasson, Wayne, "Retarders Keep Moisture, The Enemy Within, At Bay," *RSI*, August, 1990, pg. 38.
- Walters, Robert B. "Condensation Modeling of EPDM Single-Membrane Roof Systems," (proceedings from the) *Second International Symposium on Roofing Technology*, 1985, pg. 391.

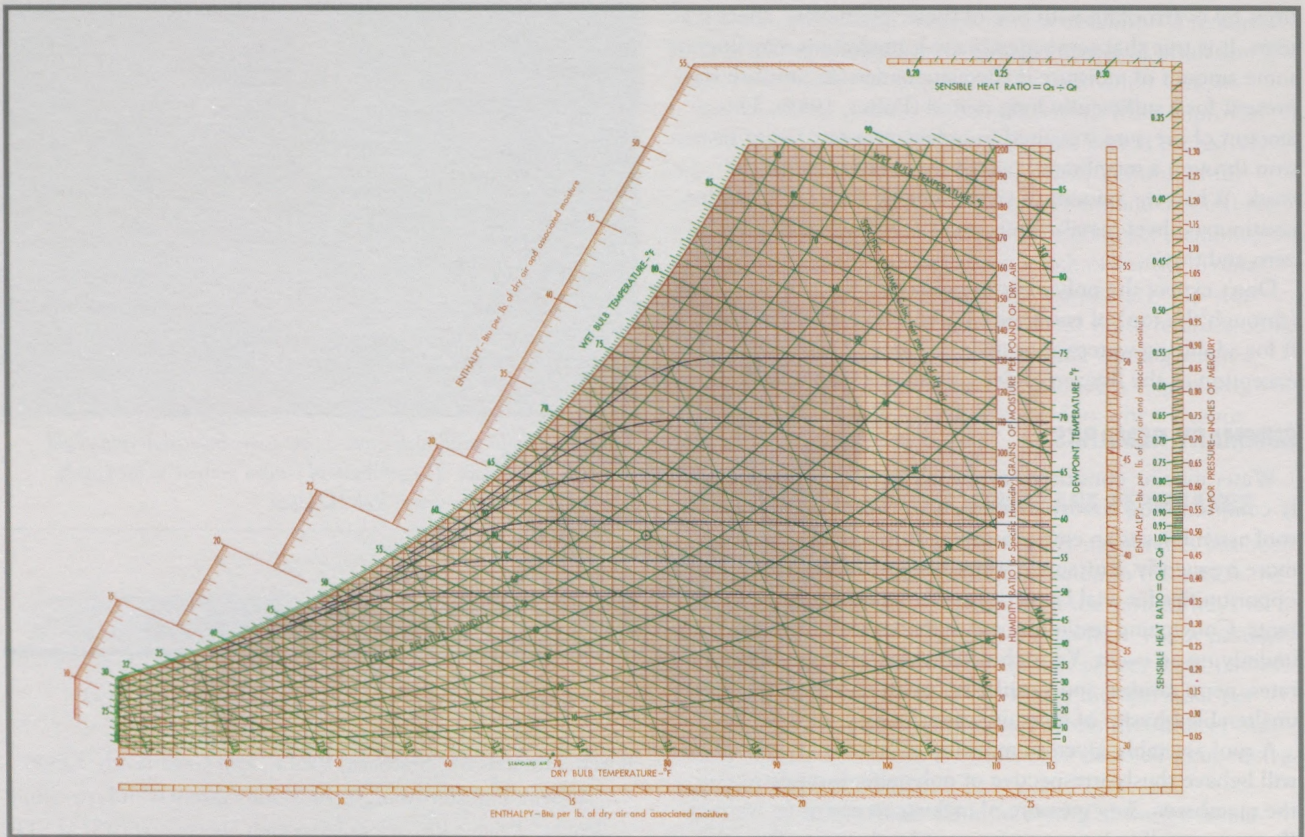
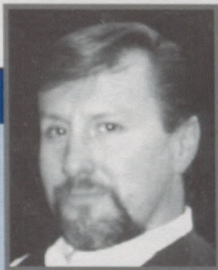


Figure 7: The psychrometric curve for dew point analysis is infallible for interpreting condensation potential. Moisture gain in spite of proper curve interpretation is a sure sign of other culprits. (Figure courtesy of Trane.)



## About The Author

**Lyle D. Hogan** is a senior engineer with GeoScience Group, Inc., working out of the firm's Greensboro, NC office. He is a registered engineer, a Registered Roof Consultant, a Fellow of RCI, and Senior Editor of Interface journal. Lyle received the 1996 Horowitz Award for his contributions to Interface.

## ICC and NFPA Go Separate Ways

The relationship between the International Code Council (ICC) and the National Fire Protection Association (NFPA) for the joint development of the ICC International Fire Code has been terminated by agreement of both parties. Both parties have agreed that their differences as to the objectives of the ICC are too substantial to result in a long-standing, mutually beneficial relationship.

The main objective of the ICC is to produce a single, complete set of model construction codes for use by the nation's cities, counties and states. The NFPA has indicated that they will continue to produce their own Fire Prevention Code

independent of the ICC, which intends to continue developing an International Fire Code.)

The ICC held hearings on the change proposals submitted to the First Draft of the International Fire Code in April. The ICC is an organization of the three model code groups in the U.S.—Building Officials and Code Administrators (BOCA) International Inc., International Conference of Building Officials (ICBO) and Southern Building Code Congress International (SBCCI).

For more information, visit ICC's web site at <http://www.intlcode.org>.