or similar device that passes over reading surface **23** of the display apparatus and pushes all the pins to their lowest possible position. In a computer controlled display, the action of the resetting device can be controlled by the overall control algorithm of the display. If the resetting device contacts the parts of the display where the users put their fingers, it is desirable to include a guard to prevent the users' fingers from being caught in the resetting device. A safety interlock can also help in the prevention of injury or damage to the display.

Tactile graphic images embossed on paper or plastic represent a well-known and popular medium. Embossed images are somewhat different from tactile images formed by discrete pins, because in an embossed image the paper or plastic sheet forms a continuous connection between adjacent points (similar in concept to the tent material draped from pole to pole in a circus tent), which may tend to smooth out the sensations produced by the discrete nature of the embossed points, and (for example) make lines and curves feel continuous to a greater extent than would otherwise be the case.

While the use of discrete pins **21** with large rounded heads **31** as heretofore described produce a sensation of continuity comparable to that of embossed images on paper with the same pin spacing, there may be applications for which the additional smoothing effect of a continuous sheet is desirable. This can be implemented by placing a thin sheet of flexible material **101** between the image produced by the pins and the user's fingers (see FIG. **13**). Holding the flexible sheet against the pins with a partial vacuum can produce an even closer approximation to the sensation of reading embossed images on paper. An additional benefit of this approach is a reduction in contamination of the internal components of the display by dirt and other substances introduced from the fingers and by environmental exposure.

A possible alternate use of a flexible sheet is the application of a tactile graphic array as a mold or form for production of a permanent record of a displayed image. As an example, the user interacts with the refreshable tactile graphic display system, and occasionally wants to save a copy of what is displayed for later reference or to transfer to another user who may not have a refreshable display. A thin sheet of thermoplastic material **103** is heated and placed against the display surface (see again FIG. **13**). The material can be pressed or vacuum formed against the surface of the display until it cools and hardens, after which time it can be removed, and retains an image of what was displayed. This capability may also be helpful to a user who is performing design work or conducting research and needs simultaneous access to multiple tactile graphic images (more than can be shown on the refreshable display at one time). The use of the same surface for direct reading by the user and for production of hardcopies represents an additional convenience for the user.

A two-level display (each pin either extended or not extended) is sufficient for displaying lines, curves, and textured 2-dimensional surfaces, and thus provides the functionality of 2-dimensional graphics. For some users who have learned to interpret perspective, this may include the capability to display 2-D perspective drawings of 3-D objects. A higher level of tactile graphic representation would present a true three-dimensional tactile graphic object. An extended array tactile graphic display is not capable of presenting full 3-D tactile graphic images, but it can be used in an intermediate format that conveys some three-dimensional information. This format requires that the pins be settable to multiple levels, and the resulting tactile image is comparable to relief sculpture (with the requirement that there be no undercutting of the raised portions of the image). Relief in non-refreshable media such as plastic is currently used for accessibility purposes, but use is limited by cost (much higher than 2-level embossed paper) and volume storage requirements.

If a multiple-level display has large intervals between the allowed levels (required by some of the locking mechanisms described hereinabove), then the stepwise nature of the depth presented may impede the reading of the display. This difficulty may be alleviated by measures to smooth the apparent surface of the display, for example by use of a flexible sheet as described above and shown in FIG. **13**. As described for two-level displays, a multi-level display can also be designed for occasional use as a form for molding of permanent copies of the image displayed, by the application of a heated thermoplastic sheet.

An extended array tactile graphic display must follow a specified sequence of actions in order to ensure correct operation and to prevent harm to the user or damage to the display. In production design it is desirable to include layer interlock mechanisms to make sure that the allowed operational sequences are followed. For example, in a display with a two-stage pin retention, a sensor should detect whether the pins are locked (e.g., sensing position of the pin locking mechanism employed) and no effort to set or reset the pins while the lock is engaged should be supported. If a roller or other device is passed over the reading surface to reset the pins, then a sensor should detect whether or not the user is currently touching the reading surface—this could be implemented by requiring the user to press buttons (and therefore remove the hands from the display), or by use of position detection sensors, or by requiring that a cover be placed over the display during reset, or by a combination of the above. The specific interlocks needed depend on the specific implementation details of the display.

For computer implementation of the array of this invention, the following is a normal sequence of operations. The user first issues a command for the display of a tactile graphic image. The system converts the graphical image to a format suitable for the display, e.g. raster or vector format, and if necessary converts the image to a map for setting of individual pins. The system determines that the pins are unlocked (if two-stage pin retention is used) and ready for setting. If there is an undesired image already on the display, the pins are reset. The selected pins are set to produce the desired tactile graphic image and, if two-stage pin retention is used, the pins are then locked. The user is given a signal that the display is ready to read and the user reads the display. If desired and if the display has the capability, a permanent hardcopy of the displayed image can be made. If the user so desires, one or more incremental additions can be made to the displayed image. If two-stage pin retention is used, the pins are unlocked before each incremental addition, then re-locked, and the user signaled that the display is again ready for reading. Finally, when the user signals that the displayed image is to be erased or replaced, if two-stage pin retention is used the pins are unlocked and the pins are reset to the default position. The display is now ready to display a new graphic image.

Computer control is not necessary for implementation of the extended tactile graphic array. There can be considerable value for accessibility in a low-cost device that lets the user draw and read tactile images, then erase the images to enable further drawing. To be economically attractive, a non-computer-driven implementation of this technology must be extremely low in cost. In this cost range, the favored method