TLC LITERATURE REVIEW (C)
THERMAL MAPPING AND NON-DESTRUCTIVE TESTING

This review was compiled during the 1990's. It is intended to be both an introduction and a guide. It contains references to a wide range of different thermal mapping and NDT applications. It is not claimed to be an exhaustive study, and apologies are offered to authors whose publications have not been included.

DEFINITIONS

Thermal mapping can be defined as the measurement of the temperature of a surface at enough points on the surface to build up a picture of temperature differences across it.

Non-destructive testing (NDT) is assumed here to comprise thermal mapping applications outside the medical area of thermographic skin temperature measurements.

APPLICATIONS

General information on the use of TLCs in NDT applications is widely available in the literature (e.g. 1-16, 65-68). Special equipment is not usually necessary, although apparatus has been developed for special cases (e.g. 17, 18). Some representative examples of specific applications are reviewed below; the coverage is not exhaustive since most articles describe essentially the same approach applied to a large number of different test items.

Flaws, bonding faults and internal defects have been detected in **composites, laminates and honeycomb structures** (6, 7, 15, 19-38). Surface and sub-surface flaws can be detected in metals e.g. Lueder lines (regions of unstable plastic flow) in aluminum and aluminum alloys (19, 22), welded metals (39-41) e.g. cracks, voids or leaks in **pressure vessels** (8, 42) and metal adhesive bonds (19, 30, 43). Laminations in sheet metal caused by hot or cold rolling (5), stress areas and potential **fracture sites in metals** (23) and defects in springs (4, 26) have also been detected. Other studies have addressed the localization of plastic deformations during fatigue tests of metals (44), the detection of shrinkage cavities in **metal castings** (11), the testing of the thermal isolation of aluminum rivets (27) and the temperature distribution on the surface of **heating coils** (5).

Thermal mapping with TLCs has been used to test ordinary **printed circuits** (4, 6, 7, 42, 45, 46-48, 69) and multilayer **printed circuit boards** (22, 49) for electrical shorts and to inspect high resistance connections on circuit boards (8, 30). Shorts in field effect **transformers** (49) have been detected and the temperature patterns of resistors (8, 45, 51, and 27), transistors (45, 51) and transducers (52) have been visualized. Other applications cover the determination of deposits on thin film resistors (50), the detection of inhomogeneities in sapphire substrates of IR detectors (53), the observations of switching phenomena in Au, B or Si films (54, 55) and Zr-ZrO_2-Au junctions (56) and the effects of annealing and laser irradiation on amorphous films of As, Te and Ge (57). Discontinuities of electrical conductors embedded in **automobile windshields** (58), heat leaks of **refrigerator doors** (59) and heat patterns generated by vibrations of piezoelectric transducers (52, 60) and miniaturized ultra-high frequency devices (61) have also been detected.

Restricted coolant channels of **aerospace components** (19, 22), flaws in coalescers used for the filtration of jet fuel (62-64), non-uniformities of the resistive coatings of aircraft/spacecraft windows (22, 40) and hot spots for miniature heaters for spacecraft (49) have all been visualized. General reference to the use of TLCs as **heat flux sensors** has also been made (70).

Since the 1990`s when this review was originally compiled, the use of the materials in **engineering research** is continuing to grow. More detailed information is given in TLC Literature Review (B). Areas where TLCs have already made important contributions include **flow visualization** studies, wind tunnel experiments, general **temperature field indication** and **heat transfer** measurements (71-106). The materials can also be used in fluids as well as in air (107-111). The results of such research studies are having an ever-increasing commercial impact as information previously unobtainable or only able to be collected over very long periods of time can now be acquired comparatively easily and rapidly. TLCs have been used as both the unsealed liquids and in the microencapsulated form. In addition, studies have also used the shift of the color band of unencapsulated mixtures caused by shearing actions of air and water flows (112-114). Cholesterics have also been used in the NASA space program aboard Apollo 14 (115-117) and Apollo 17 (118-120) as temperature indicators in low gravity environments and to estimate heat flow through textiles (121).

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