Economic Impact of a Ban on PCB in Capacitors

The following is a short discussion of the probable economic impact of a phase-out of PCB in capacitors. Though of a largely qualitative nature, it should become evident that the effects will be pervasive and quite far reaching.

PCB is a dielectric fluid which largely controls the electrical characteristics of AC capacitors. The capacitors are used extensively in the home, in commercial buildings and in industry for fluorescent and mercury vapor lighting, television sets, refrigerators, air conditioners, electric motors and for the more efficient use of electricity (power factor correction).

The choice of PCB in these capacitors was dictated by several fortuitous properties of the fluid such as extreme stability, a relatively high dielectric constant, and fire resistance. The latter characteristic is largely responsible for the exceptional safety record of AC capacitors. The stability of PCB promotes long life and high reliability. The high dielectric constant of PCB makes possible the small size of modern capacitors.

In the late 1960's, it began to become apparent that PCB posed certain health and environmental problems. As a result Monsanto, the sole producer of PCB in the U.S., announced in January, 1976, that it intends to phase out production of PCB as soon as they are satisfied that industry's need for usable, acceptable alternative fluids has been met. Apparently this will be done irrespective of whether the EPA imposes a ban on PCB.

Although much work has been done on a variety of materials in the U.S. as well as overseas, no substitute is presently available which equals PCB in dielectric properties, fire resistance, and stability. However, since it is widely believed that Monsanto intends to close down production of PCB in a period ranging from 24 to 30 months, time for further development work on materials is running out. It seems probable that a compromise choice will have to be made which though inferior to PCB in some respects, will nevertheless maintain good electrical performance without undue safety hazards.

The elements of the compromise include a large number of characteristics in four general areas: ease of manufacture, costs, electrical characteristics, and environmental and public safety aspects. Some of the most important characteristics are shown in Table 1 for a number of proposed substitute materials. Also shown are the minimum requirements for successful substitution. All of the indicated substitutes meet these minimum requirements. However, as of today, several unresolved issues remain which make it impossible to define the optimal compromise.

Perhaps the most important area requiring further work is concerned with fire hazard and environmental acceptiblity.

With regard to fire hazard, it will be observed that the substitutes listed in the table have fire points in the range 328 to 680°F. Only PCB has no fire point. This implies that only PCB is fire resistant. The other substances, when ignited at temperatures above the fire point, will burn freely in the presence of oxygen. Opinions differ as to how significant the exact magnitude of the fire point is in view of the fact that fires in capacitors start under explosive conditions. Further study is required to clarify the relative flammability of the listed substitutes.

A considerable amount of work has been done during the last few years in order to check out the environmental acceptability of the above substitutes. It has apparently been established that all of them are superior to PCB with regard to environmental persistence and bio-magnification. Yet at this point it is not evident which of the substitutes has the optimum environmental properties.

Another area of uncertainty is the cost and availability of the listed substitutes. Some of the substitutes have so far only been produced in pilot quantities. None are produced at the high volumes required by the capacitor industry. Projections of cost necessarily relate to projections of volume, and the latter depends on whether PCB in all its applications will eventually be replaced by a single substitute.

In view of the uncertainty as to which material or materials will eventually be adopted by the capacitor industry, only very rough estimates of economic impact are possible.

One of the major cost considerations relates to the size of the capacitors. In Table 1 the relative capacitor size for given capacitance is calculated from the reported dielectric constant of each material. It should be noted, however, that in practice an additional increase in size would probably be required for the following reason. Since our experience with non-PCB dielectric fluids is limited, it cannot be assumed that they can be electrically stressed to the same extent as PCB. In order to reduce the stresses to a safer level an increase in size of the order of 15% will be required. Thus non-PCB capacitors will be larger than the equivalent PCB-impregnated devices by 15 to 90%, depending on the choice of the substitute material.

The total manufacturing cost of PCB impregnated capacitors is determined largely by the cost of materials[1] which is proportional to size. For an annual production valued at about $140 million[2] the increase in size will add an incremental cost ranging between $21 and $136 depending largely on the dielectric constant of the substitute.

The above does not include the possible higher cost of the substitute material relative to PCB. During 1975 the capacitor industry used $7 million of PCB. One of the possible substitutes is projected to sell at twice the cost of PCB. If the industry were to select this substitute, the incremental annual cost for the impregnant would amount to about $8 million, assuming a 15% size increase and would be passed on to the consumer as a $16 million price increase.

An increase in can size for given electrical specifications has another consequence which may be of great significance. The customers will have to modify their equipment to allow for the new geometry. In some cases, only a change in bracket size will be required. However, in other cases, new tooling will be needed at substantial cost to the customers.

A further consequence of the increase in can size relates to the replacement market. Since replacement capacitors will no longer be compatible with the geometry of the PCB-filled original capacitors, problems will arise when existing

equipment has to be repaired, and some equipment will have to be retired prematurely. Evidently, the economic cost of premature obsolescence will correspond to the degree the geometry must be modified.

The principal areas of potential obsolescence are air conditioners and lighting fixtures for fluorescent and vapor lamps. Worst case estimates of the potential annual costs and the assumptions on which the estimates are based are presented in Table 2 for air conditioners and in Table 3 for lighting fixtures. The initial annual cost of premature obsolescence are estimated to be $75 million for air conditioners and $50 million for lighting fixtures. However, if a useful equipment life of 10 years is assumed, 10% of the equipment will annually be retired for reasons other than capacitor failure. As a result the cost of premature obsolescence will likewise be reduced 10% per year. Thus the total cost could be of the order of $700 million spread over ten years.

Although the above described change in geometry should at least partially compensate for the lower stability of the substitute dielectric fluids, it nevertheless must be expected that the failure rate of the non-PCB capacitors will be significantly higher than that of the present capacitors. Presently the replacement market for PCB impregnated capacitors is valued at about 2-3% for large capacitors and 5-10% for small capacitors[2] and thus amounts to roughly $6 million per year. The labor required to replace the defective capacitors may well cost five times as much so that total replacement costs could add up to $36 million per year.

Much testing remains to be done before a reliable estimate of the failure rate of non-PCB capacitors can be estimated. If a doubling of failure rate is assumed and the higher cost of non-PCB capacitors is taken into consideration, the annual increase in total replacement cost would be at least of the order of $40 million. The full impact of the higher replacement cost will be felt in 7-8 years at which time most of the existing PCB capacitors have been replaced by non-PCB units.

The most disturbing aspect of a phase-out of PCB is the fact that none of the substitutes equals the characteristics of PCB with regard to fire resistance.

This implies that a significant percentage of the capacitors which fail harmlessly when impregnated with PCB will start fires when impregnated with one of the substitute oils. The severity of a fire will of course depend on the size of the capacitor, its location within the home or the factory and the innumerable special circumstances surrounding each accident.

In the absence of extensive experience quantitative estimates cannot be made regarding the expected loss of life, injury and property damage. However, it is clear that the phase-out of PCB will require a modification of regulatory codes and may produce substantial increases in the cost of fire and liability insurance.

1. Capacitor Industry Forecast, Gnostic Concepts, Inc.

2. Study of the Potential Economic Impacts of the Proposed Toxic Substances Control Act as Illustrated by Senate Bill 5776 (February 20, 1975) Prepared for the Manufacturing Chemists Association by Foster D. Snell, Inc.

TABLE 1

Characteristic	Limits	PCB (1016)	Substituted Aromatic Compound	Phthalate Esters	Synthetic Hydro-carbons	Silicone Oil	Minera Oil
Boiling Point (°C)	> 95	> 300	> 300	> 300	296°C	> 300	> 300
Flash Point/Fire Point (°F)	> 300/?	358/None	345/390	430/495	303/328	605/680	300/37
Pour Point (°C)	< -35°C	-19	-45	-45	-47	-50	-45
Vapor Pressure	Negligible at 100°C	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Viscosity (CS)		2.1	-	4.3	2.0	20	3
Dielectric Constant	2-10	5.9	4.4	5.0	6.1	2.8	2.2
Dielectric Strength (KV/.1")	> 30	35	35	35	35	35	30
Power Factor (%)	<< 10%	1.0	1.0	2.5	2.0	0.05	0.1
Volume Resistivity	$> 10^{10}$ Ω	10^{12}	10^{12}	10^{12}	10^{12}	10^{14}	10^{12}
Relative Capacitor Size		1.0	1.16	1.08	.99	1.51	1.77

TABLE 2

Number of capacitors in air conditioners	120,000,000
Number of above which connot be replaced with larger units owing to space limitations	60,000,000
Cost of associated equipment per capacitor	$250
Value of above after 50% depreciation	$125
Number of capacitors failing annually	600,000
Depreciated value of equipment associated annually with failed capacitors (600,000 x $125)	$75,000,000

TABLE 3

Number of AC capacitors in lighting fixtures	440,000,000
Number of above which cannot be replaced with larger units owing to space limitations	400,000,000
Cost of associated equipment per capacitor	$25
Value of above after 50% depreciation	$12.50
Number of capacitors failing annually	4,000,000
Depreciated value of equipment associated annually with failed capacitors (4,000,000 x $12.50)	$50,000,000