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AEROSPACE INFORMATION REPORT

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Aerospace Fluid Power - Waste Reduction Practices for Used Phosphate Ester Aviation Hydraulic Fluid

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1. SCOPE:

This SAE Aerospace Information Report (AIR) covers the generation of used phosphate ester aviation hydraulic fluid (AS1241) that is deemed waste because it does not meet in-service limits for use in aircraft. This document also lists the relevant United States Environmental Protection Agency (U.S. EPA) regulations on used hydraulic fluid that are in force at the time of this report's publication. Regulations of other countries as well as those for states and municipalities should be consulted prior to initiating any of the waste disposal recommendations listed here.

This document recommends actions for minimizing waste hydraulic fluid as well as practices for disposing of waste hydraulic fluid.

1.1 Purpose:

The purpose of this document is to instruct the users of AS1241 hydraulic fluid on appropriate actions for minimizing the generation of waste hydraulic fluid, thereby allowing for longer service life of the fluid and reducing operating costs associated with the handling and disposal of waste fluid.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS1241	Phosphate Ester Fire-Resistant Aviation Hydraulic Fluid
AS4059	Aerospace Cleanliness Classification for Hydraulic Fluids
ARP5376	Aerospace Fluid Systems and Components - Methods, Locations and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids

2.2 U.S. EPA Publications:

Available from Government Institutes Inc., No. 4 Research Place, Rockville, MD 20850.

U.S. EPA 40CFR Part 279 - Management Standards for Generating, Transporting, Reusing, Recycling, and Disposing Used Oils (Federal Register, September 10, 1992, pp. 41566-41626)

2.3 NAS Standards:

Available from Aerospace Industries Association, 1250 Eye Street NW, Washington, DC 20005-3924.

NAS 1638 Cleanliness Requirements of Parts Used in Hydraulic Systems

2.4 European Union Directives:

Available from Office for Official Publications of the European Communities, L-2985 Luxembourg.

Council Directive of 12 December 1991 on Hazardous Waste (91/689/EEC), Official Journal, L377 p. 20, 31 December 1991

Council Regulation (EEC) on the Supervision and Control of Shipments of Waste within, into, and out of European Community (EEC No. 259/93), Official Journal, L30 p. 1, 6 February 1993

3. GENERATION OF WASTE HYDRAULIC FLUID:

Waste hydraulic fluid can be generated in four different ways:

1. excessive external system leakage
2. normal maintenance activity
3. fluid degradation
4. fluid contamination

The release of hydraulic fluid during system operation as well as during maintenance is often unavoidable. Certain actions, however, can be taken to minimize the contamination of hydraulic fluids during storage and thereby effectively extend the service life of the fluid.

3.1 System Leakage of Hydraulic Fluid:

Commercial aircraft hydraulic systems operate at 3000 psi (20.7 kPa) and the potential for leaks always exists. By design, a film of hydraulic fluid external to the hydraulic system is necessary for the proper operation of specific hydraulic devices. For example, actuator rods are coated with a hydrodynamic layer of hydraulic fluid to enable proper lubrication and sealing. Similarly, pump shaft seals rely on a thin coating and constant replenishment of hydraulic fluid for lubrication and cooling.

When a seal fails, external leakage is excessive and hydraulic fluid is unnecessarily released into the atmosphere. Furthermore, the fluid can pool inside the aircraft thereby creating a source of waste.

3.2 Maintenance Activities:

Maintenance on commercial aircraft hydraulic systems will always release a quantity of hydraulic fluid from the system. In most instances, the released fluid is collected in a catchpan. Also, some fluid is retained in the removed component which may end up in the repair shop.

3.3 Thermal/Oxidative/Hydrolytic Degradation:

The phosphate ester component of AS1241 hydraulic fluids are susceptible to degradation if exposed to high temperatures, long in-service duration, and/or contamination. Degradation occurs by any of several chemical mechanisms which either generate acidic species and/or degrade the additive package of the formulated product.

High temperature operation and prolonged in-service duration are largely dependent upon the aircraft models' hydraulic system designs and the specific operator's maintenance practices. Contaminants such as water and chlorinated solvents can compromise AS1241 fluid service life by reacting with the phosphate ester to form acids and/or decompose additives that protect the hydraulic components from such effects as rust or electrochemical erosion. Particulate contaminants provide sites for catalyzing the reactions that form acids. AS1241 hydraulic fluids contain an acid control additive that reacts with the acid species in order to control the fluid's acidity to an acceptable level such that corrosive attack on system hardware is not a problem. Extreme system operating conditions (>225F/107C) and/or prolonged service time with low fluid topoff rates, however, can result in total depletion of this acid control additive and generate a high acid fluid.

Most airframe manufacturers (AFMs) and original equipment manufacturers (OEMs) have established in-service limits for fluid acidity (Table 1). Prolonged operation with an excessively high acid fluid may result in corrosive damage of internal metal surfaces. This corrosion mechanism also generates metal phosphate salts which may precipitate from solution and possibly inhibit component efficiency or cause additional wear at moving surfaces.

Chemical testing of the hydraulic fluid can determine serviceability. If the analyses determine the fluid to be out of any of the AFM's in-service limits, then the fluid should be drained from the system and replaced with new fluid until all in-service limits are met. In most cases, a reservoir drain and refill is sufficient. In extreme cases, however, a more extensive replacement of system fluid is required.

3.4 Contamination:

The hydraulic fluid that is released from a hydraulic system should never be reintroduced into an aircraft's hydraulic system because of the possibility of contamination which may result in operational problems or permanent damage to sensitive components.

Contamination can take two general forms, solid particles or chemicals which are typically water, solvents and cleaners, debris from seal wear and internally generated wear particles, and other fluids used in servicing the aircraft. Most AFMs and OEMs have in-service limits on contamination in order to improve reliability and lower maintenance costs associated with hydraulic system operation (Table 1). Regular fluid sampling per ARP5376 is recommended to ensure optimum efficiency of system operation.

TABLE 1 - Airframe Manufacturers' In-Service Limits for AS1241 Hydraulic Fluid[5]

ANALYSIS	BOEING[1]	DOUGLAS	AIRBUS	BOMBARDIER	LOCKHEED	BAE	FOKKER
Appearance	No cloudiness, phase separation or precipitation. Any color acceptable.				No cloudiness or precipitation. Color: blue/purple to gray		
Specific Gravity @ 25°C/25°C	0.995-1.066	0.900-1.066	0.995-1.066	0.995-1.066 0.995-1.020[7]	0.989-1.065	0.995-1.006	0.999-1.057
% Moisture (max.)	0.8	0.5	0.5	0.6	1.0	0.6	0.6
Neutralization No. mg KOH/g (max.)	1.5[3]	1.5	1.5	1.5	1.5	0.75	1.0
Kinematic Viscosity @ 100°F/38°C, cS	6.0-12.5	7.0-12.0	6.0-12.5	7.0-12.5	7.0 (min.)	6.0 (min.)	7.0 (min.)
Elemental Contamination (ppm max.)[2]							
Calcium	50	-	-	-	-	-	
Potassium	50	-	-	-	-	-	
Sodium	50	-	-	-	-	-	
Chlorine	200	200	200	200	200	200	
Sulfur	500	-	-	-	-	-	
Particle Contamination #/100ml (max.)[6]							
5-15 µm	128000[4]	128000	128000	64000[8]	64000	128000	128000
15-25 µm	22800	22800	22800	11400	11400	22800	22800
25-50 µm	4050	4050	4050	2025	2025	4050	4050
50-100 µm	720	720	720	360	360	720	720
>100 µm	128	128	128	64	64	128	128

[1]Boeing in-service limits are applicable to Gulfstream.
[2]Contamination means quantities in excess of those introduced as part of the additive package or basestock.
[3]Boeing has established a max. neutralization number of 1.0 for the B757 Center system.
[4]Boeing does not have specific particle contamination levels for in-service fluid. New aircraft are delivered with fluid that meets or exceeds NAS 1638, class 9 which are included in this table for reference.
[5]Values quoted may change per airframe manufacturer actions. Consult service manual if in doubt.
[6]Particle count limits stated per NAS 1638 in accordance with airframe manufacturers' documents. SAE recommends AS4059 when automatic particle counters are used.
[7]Applicable to Global Express
[8]If Class 9 contamination found, continued operation acceptable for an additional 200 h prior to change.

3.4 (Continued):

Testing of the hydraulic fluid by an approved testing laboratory can determine contamination levels of in-service fluid. Solid particles can be removed by numerous filtration stages present on both the ground service equipment and aircraft hydraulic system. Filter maintenance may be warranted if particle levels are high. The chemical contaminants, however, are not readily removed but can likewise render damage to the aircraft's hydraulic system.

If chemical contamination is outside of limits, fluid must be drained from the system and replaced with new fluid. It is recommended that operators of aircraft consult the service manual for up-to-date revisions to the in-service limits.

4. REGULATORY CATEGORIZATION OF USED HYDRAULIC FLUID:

The legislation relating to the classification of used AS1241 hydraulic fluid as a "hazardous waste" and the regulations governing its transport and disposal on a national and international basis, differ considerably among countries. Therefore, this document has been prepared with emphasis on U.S. federal legislation and a less extensive review of European and other world area legislation.

New AS1241 hydraulic fluid does not contain any ingredients that would make it a "hazardous waste" under current U.S. EPA regulations, however, used fluid may carry a "hazardous waste" classification because of contamination by either of two general sources, trace heavy metals and/or chlorinated solvents. The U.S. EPA regulates the treatment, storage, and disposal of chemical waste. The United States Department of Transportation (U.S. DOT) controls transport of waste.

Table 2 presents the current list of chemicals and their regulatory levels for defining "hazardous waste" according to the U.S. EPA.

In Europe, key European Union directives are EEC 91/689 and EEC 259/93. EEC 91/689 defines a broad list of generic types of "hazardous waste", and the possible constituents and contaminants in the fluid which could render it hazardous in terms of health effects, e.g., toxicity, carcinogenicity, and sensitizing/irritating effects.

EEC 259/93 defines the conditions applying to transfrontier movement of used AS1241 hydraulic fluid both inside the European union and for export/import movements.

The regulations of local municipalities, states, and other countries should be consulted before classifying and disposing of waste hydraulic fluid since these may differ from those in the United States. For example, in Japan, the Department of Environment is the regulating body. In some countries, reference to the U.S. EPA regulations is made.

Recently, the U.S. EPA issued revised Standards for the Management of Used Oil, 40CFR Part 279 (Table 3). These standards govern recycling and disposal of "on-spec" used phosphate ester hydraulic fluids in lieu of the federal hazardous waste program in states that have adopted these used oil regulations. Used fluid that does not meet these "on-spec" criteria must be processed as "hazardous waste". If economics are favorable, processing "on-spec" used fluid under the more stringent "hazardous waste" regulations is permitted.

TABLE 2 - U.S. EPA Regulatory Levels for Contaminants

EPA HW No.	Contaminant	CAS No.	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	200.0
D024	m-Cresol	108-39-4	200.0
D025	p-Cresol	106-44-5	200.0
D026	Cresol	....	200.0
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10.0
D035	Methyl ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	5.0
D010	Selenium	7782-49-2	1.0
D011	Silver	7440-22-4	5.0
D039	Tetrachloroethylene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethylene	79-01-6	0.5

TABLE 2 - U.S. EPA Regulatory Levels for Contaminants (Continued)

EPA HW No.	Contaminant	CAS No.	Regulatory Level (mg/L)
D041	2,4,5-Trichlorophenol.	95-95-4	400.0
D042	2,4,6-Trichlorophenol.	88-06-2	2.0
D017	2,4,5-TP (Silvex)	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

TABLE 3 - U.S. EPA Used Oil Fuel Specification[1]

Constituent/Property	Allowable Level
Arsenic	5 ppm maximum
Cadmium	2 ppm maximum
Chromium	10 ppm maximum
Lead	100 ppm maximum
Flash point	100 °F minimum
Total halogens	4000 ppm maximum

[1] The specifications do not apply to mixtures of used oil and hazardous waste that continue to be regulated as hazardous waste.

Source: Adapted from 57 FR 41615.

4.1 Trace Heavy Metals:

Trace heavy metals are incorporated into the fluid during use because of normal wear and attrition of hardware. In general, waste materials are classified by the U.S. EPA as "hazardous waste" if any one regulatory level is exceeded (Table 2). However, in the case of used AS1241 hydraulic fluid, the limits are relaxed for several heavy metals (cadmium (2.0 ppm), chromium (10.0 ppm), and lead (100 ppm)) in an effort to promote recyclng when feasible (Table 3).

4.2 Chlorinated Solvents:

Chlorinated solvents have been used extensively in manufacturing and repair stations to clean metal parts and components prior to assembly or packaging. 1,1,1-trichloroethane (TCA) and chlorofluorocarbons (Freon®) are preferred for these applications because of their excellent degreasing properties and fast evaporation.

4.2 (Continued):

These solvents find their way into hydraulic systems and hydraulic test stands and may affect performance attributes of the AS1241 hydraulic fluid such as thermal stability and acidity control, erosion resistance, and O-ring seal swell. Furthermore, the U.S. EPA defines hydraulic fluid (or any fluid waste) as "hazardous" even if the fluid contains relatively low concentrations of these solvents.

5. ACCEPTABLE METHODS OF DISPOSAL OF USED HYDRAULIC FLUID:

In the United States, landfill disposal of any liquid waste is illegal and carries heavy penalties. Whereas other countries' regulations may vary, destruction of waste hydraulic fluid is strongly recommended. Alternative uses for reclaimed phosphate ester basestock may also be feasible.

Both landfill and incineration methods are permitted by European Union legislation. Regulations of individual nations reflect societal or geographic preferences.

It is evident that, particularly in Europe, national and international administrative procedures are complex with regard to notification and transport documentation and that further changes can be expected.

5.1 Hazardous Waste Incineration:

Hazardous waste incineration is available through a number of reputable firms. In most cases, these firms can handle a blend of AS1241 fluid and other liquid wastes. In certain instances, however, segregation of used hydraulic fluid can lower the cost of incineration because of the hazardous waste regulations cited in Section 4. For example, mixing 1 gal of waste hydraulic fluid that may be "hazardous waste" because of high metal content with 100 gal of other liquid wastes could render 101 gal of "hazardous waste".

Hazardous waste is always more expensive to transport and incinerate. Furthermore, at concentrations specified by the hazardous waste incinerator, water, chlorine, and heavy metal contaminants increase the cost of incineration.

5.2 Energy Recovery Incineration:

One option to destruction in hazardous waste incinerators is energy recovery incineration. Alternative fuel blenders have taken used hydraulic fluid and employed it as a fuel for cement kilns. This alternative fuel option allows for recovery of the BTU value of the fluid. In the United States, these fuel blenders and cement kilns are regulated by the U.S. EPA to ensure proper and responsible operations. The used hydraulic fluid is still classified as hazardous and, therefore, transporters and fuel blenders must be licensed handlers of hazardous waste.

Segregation of the used hydraulic fluid from other liquid wastes is recommended because, as with hazardous waste incinerators, fees are based on fluid quality, i.e., water, chlorine, and heavy metals.

6. RECOMMENDED PRACTICES TO MINIMIZE FLUID WASTE:

Specific actions can reduce the volume as well as alleviate the regulatory burdens associated with waste hydraulic fluid. These practices can lead to reduced costs for the generator of the waste and society benefits from a reduction of waste chemicals.

6.1 Hydraulic System Designs:

Modern aircraft hydraulic systems and components have been designed for improved efficiency and mechanical reliability. Hence, there is less maintenance and leakage which contribute to the volume of hydraulic fluid that should not be reintroduced into the aircraft.

In recent years across the aviation industry, the volume of AS1241 hydraulic fluid used per hydraulic system volume has decreased, an indication that better equipment reliability translates to reduced fluid attrition and longer fluid service times.

Because of this trend to longer fluid service times, it is recommended that regularly scheduled testing of fluid quality be performed to ensure that AFM in-service limits are met.

6.2 Storage and Handling of Hydraulic Fluid:

Proper storage and handling procedures can significantly reduce the generation of waste hydraulic fluid.

6.2.1 Storage of Inventory Stock: AS1241 hydraulic fluid should always be stored in its original container. Inventory stock should be stored in a clean, dry environment to prevent dirt and moisture from accumulating on the containers and around drum bung openings. Drums should be stored in a horizontal or angled position. Preferably, hydraulic fluid should be stored at ambient temperature and segregated from other fluids thereby reducing the possibility of inadvertent mix-up of products.

6.2.2 Storage of In-Service Fluid: Protect in-service fluid from dirt and moisture. The hydraulic fluid contained in hydrants and reservoirs should be blanketed with either desiccated air or dry nitrogen, and breathers and vents should be equipped with desiccant filters.

6.2.3 Solvents, Cleaners and In-Service Hydraulic Fluid: With the prevalence of cleaners and degreasing solvents in hydraulic repair shops, contamination of in-service hydraulic fluid with these chemicals is a concern.

A review of in-service AS1241 hydraulic fluid reveals that chlorine contamination occurs most often and to higher concentrations in hydraulic test stands (Figure 1). It is common practice to clean parts with a degreasing solvent after testing new and overhauled parts. In addition, some operators may rinse down the test stand with the solvent.

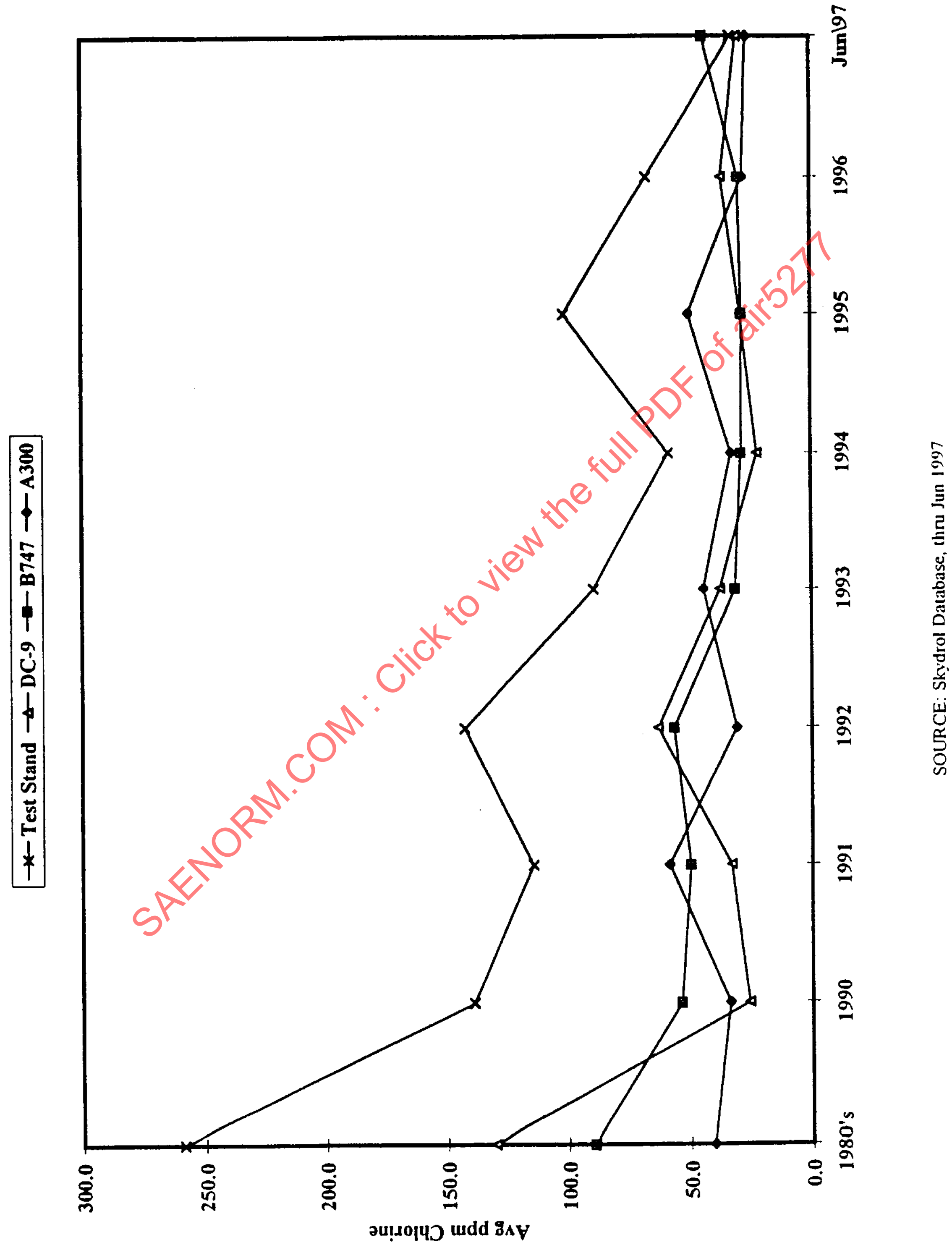

FIGURE 1 - Average Chlorine (ppm) in Industry Fleets