Introduction:

Corrosion is and has always been a serious issue for all types of airplanes. Through the recent years, several inspection programs, procedures, and materials have been developed to keep corrosion as far away as possible from airplane components and structures.

Corrosion is the electrochemical deterioration of a metal or composite structure caused by its chemical reaction with the surrounding environment. While new and better materials are continuously being developed, this process is offset, in part, by a more aggressive operational environment which makes corrosion a complex phenomenom. It can take many different forms and the resistance of aircraft materials to corrosion can drastically change with only a small environmental change.

Within this scenario, "prevention" is the key.

In this article, the focus will be in the environment, that is, the geographical locations of the globe and the respective effect that they can have on airplanes in terms of corrosion. The main objective is to present the basics behind the current preventive recommendations contained in the Maintenance Manuals, more specifically in terms of engine compressor washing schedules.

Most of the article was based in the FAA AC (Advisory Circular) 43-4A "Corrosion Control For Aircraft" which was published in 1991 and contains a large amount of data regarding identification and treatment of corrosive attack on aircraft structure and engine materials.

Discussion:

Following paragraphs were extract from the AC 43-4A:

Paragraph 411 Factors in Corrosion Control:

d. **Geographical Location and Environment**. This factor concerns systems exposed to marine atmospheres, moisture, acid rain, tropical temperature conditions, industrial chemicals, and soils and dust in the atmosphere. Limit, whenever possible, the requirement for operation of aircraft in adverse environments.

(1) **Moisture** is present in the air as a gas (water vapor) or as finely divided droplets of liquid (mist or fog) and often contains contaminants such as chlorides, sulfates and nitrates, which increase its corrosive effects. Condensed moisture which evaporates will leave its contaminants behind. Condensed moisture and its contaminants can also be trapped in close fitting, wettable joints, such as faying surfaces and be drawn along poor band lines by capilarity action.

(2) **Salt particles**, when dissolved in water, form strong electrolytes. Normal sea winds carry dissolved salt which makes coastal environments highly corrosive.

(3) **Industrial Poluants** (such as carbon, nitrates, ozone, sulfur dioxide and sulfates) contribute to the deterioration of nonmetallic materials and can cause severe corrosion of metals.

(4) **Warm moist air**, normally found in tropical climates accelerates corrosion while cold dry air normally found in artic climates reduces corrosion.

Paragraph 412 Preventative Maintenance:

a. **Prevention**. Corrosion prevention of aircraft structure depends on a comprehensive corrosio prevention and control plan, implemented from the start of operation of an aircraft, which includes:

(1) Adequately trained personnel in:

i. Recognition of corrosion inducing conditions

ii. Corrosion identification techniques

iii. Corrosion detection, cleaning and treating, and

iv. Lubrication and preservation of aircraft structure and components

(2) Inspection for corrosion on a scheduled basis.

(3) Through cleaning, inspection, lubrication and preservation at prescribed intervals. Suggested intervals based on operating environment (see figures 4-15 through 4-20) are:

i. Mild zones: Every 90 days

ii. Moderate zones: Every 45 days

iii. Severe zones: Every 15 days

(4) Prompt corrosion treatment after detection.

(5) Accurate record keeping and reporting of material or design deficiencies to the manufacturer and the FAA.

(6) Use of appropriate materials, equipment and technical publications.

(7) Maintenance of the basic finish systems.

(8) Keeping drain holes and passages open and functional. Sealants, leveling compounds, miscelaneous debris or corrosion inhibitors should not block drain paths.

(9) Replacing deteriorated or damaged gaskets and sealants (using non-corrosive type sealants) to avoid water intrusion and entrapment which leads to corrosion.

(10) Minimizing the exposure of aircraft to adverse environments, such as hangaring away from salt spray.

Figure 4-15: North America Corrosion Severity Map

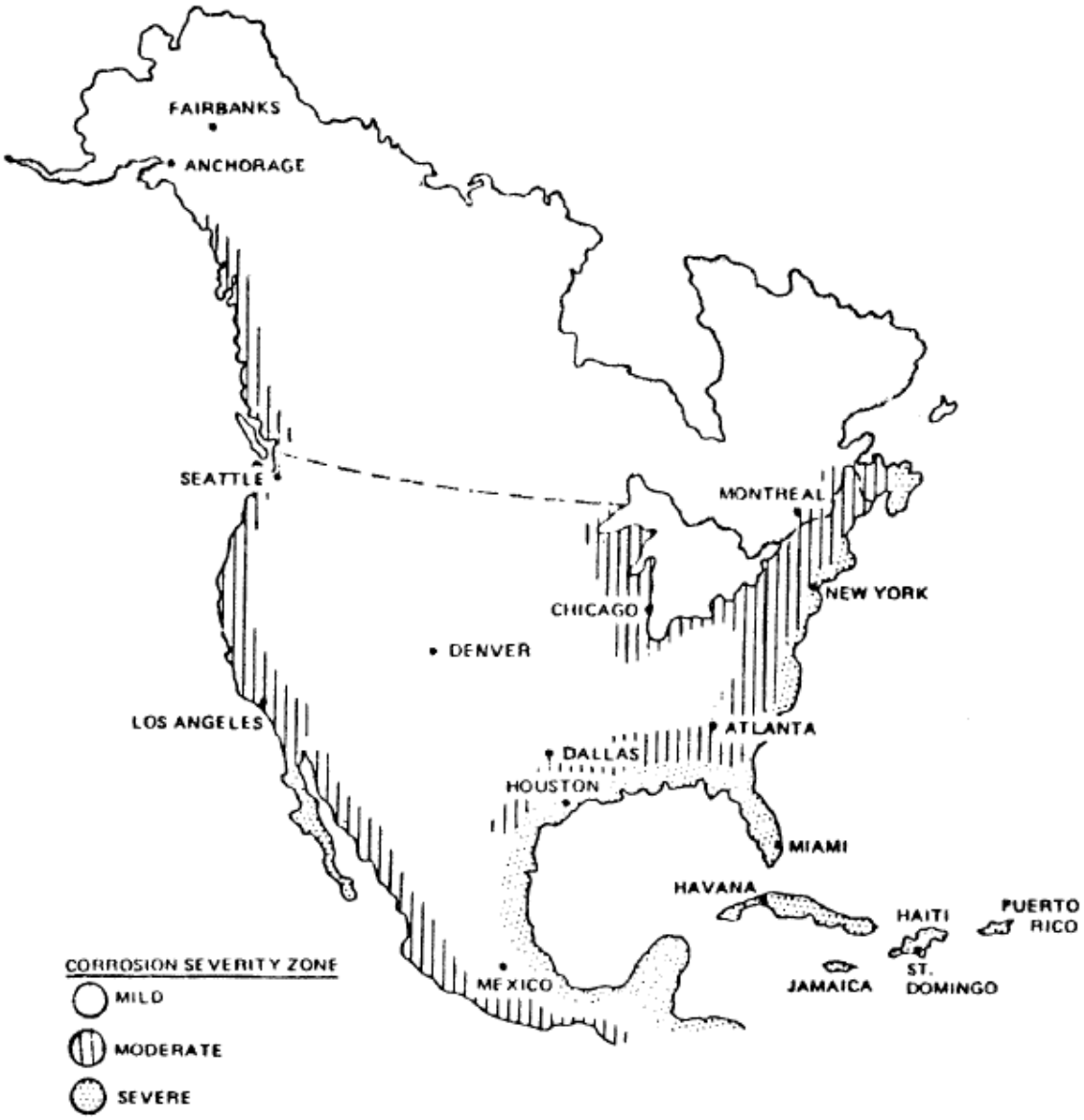


Figure 4-16: South America Corrosion Severity Map

Figure 4-17: Africa Corrosion Severity Map

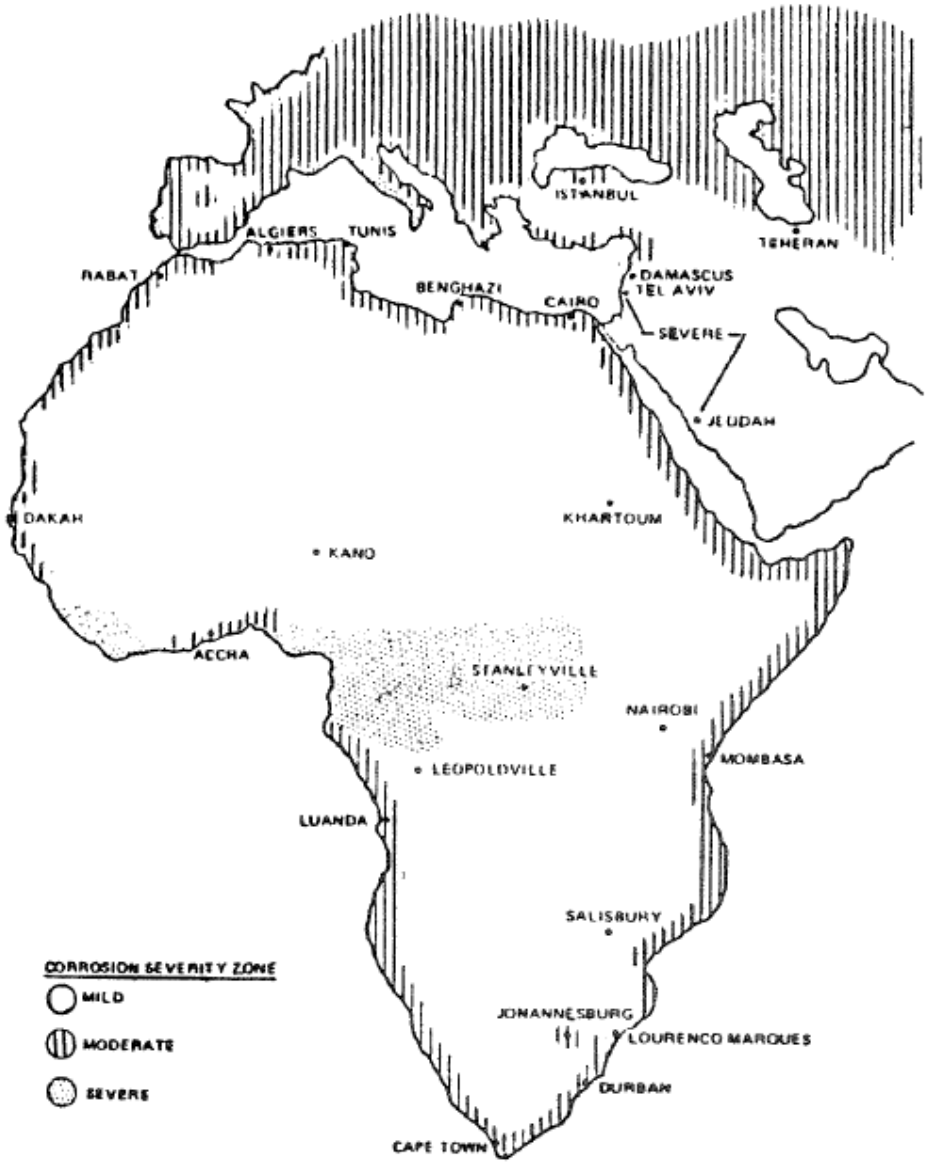


Figure 4-18: South Pacific Corrosion Severity Map

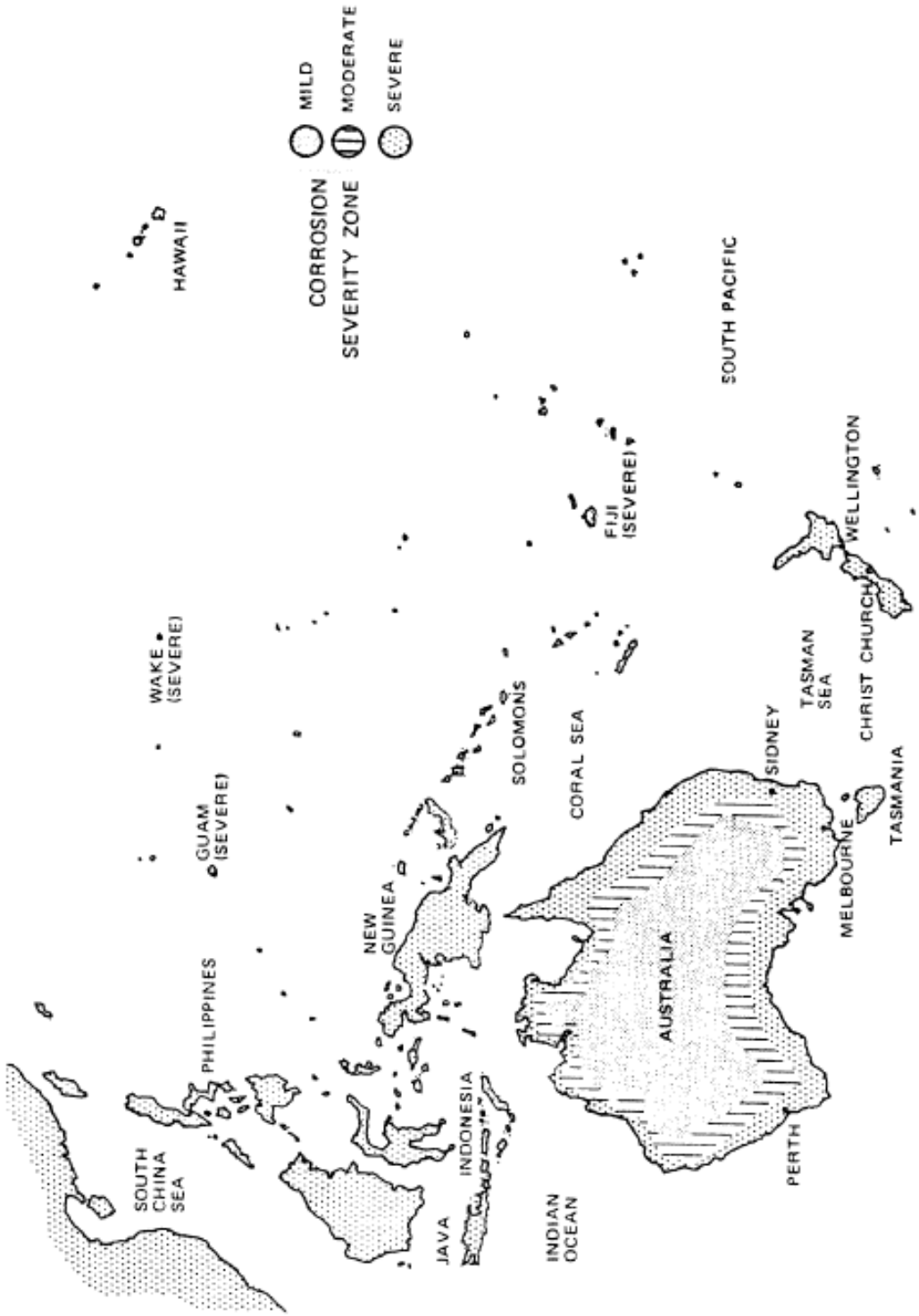


Figure 4-19: Asia Corrosion Severity Map

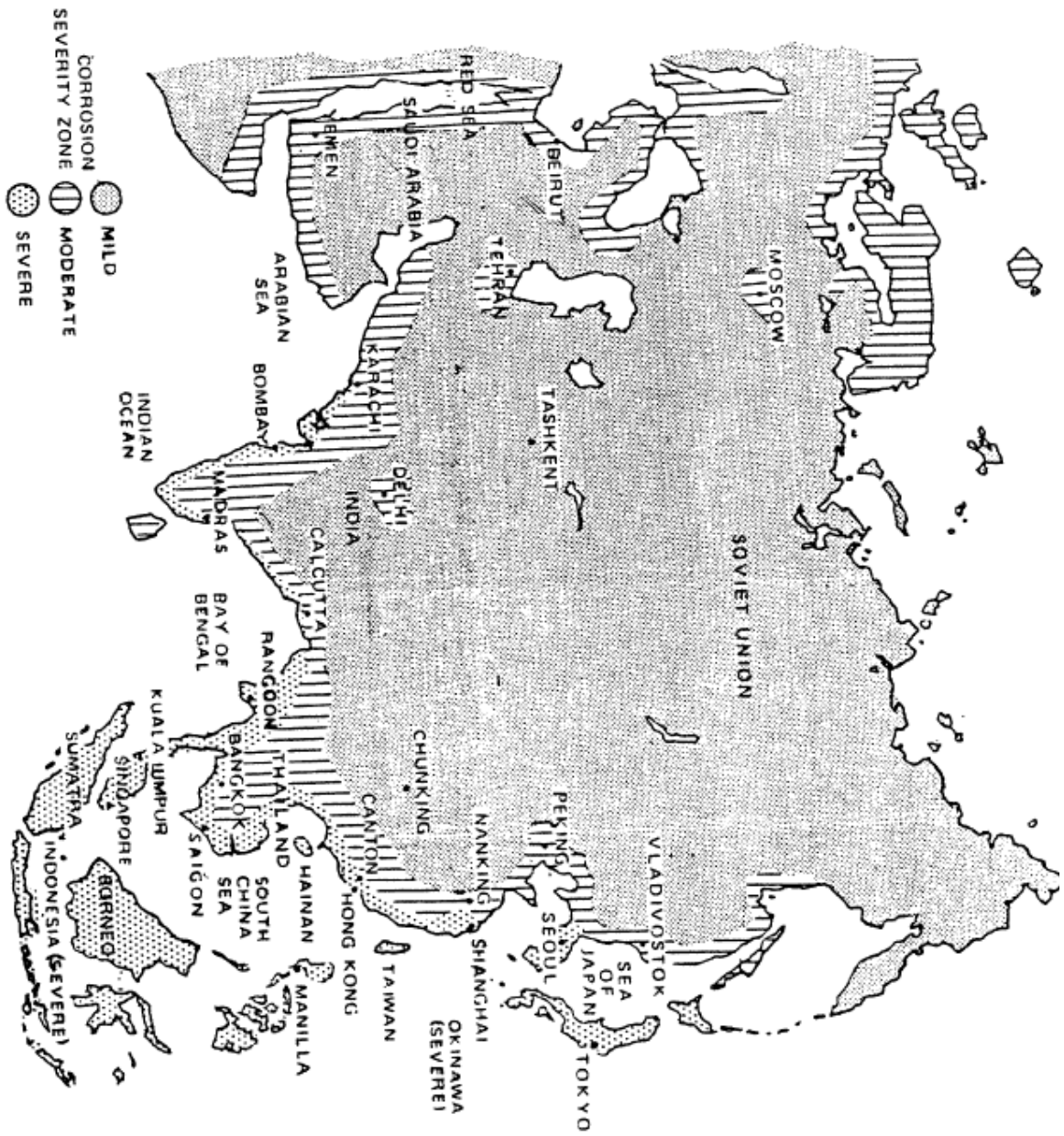
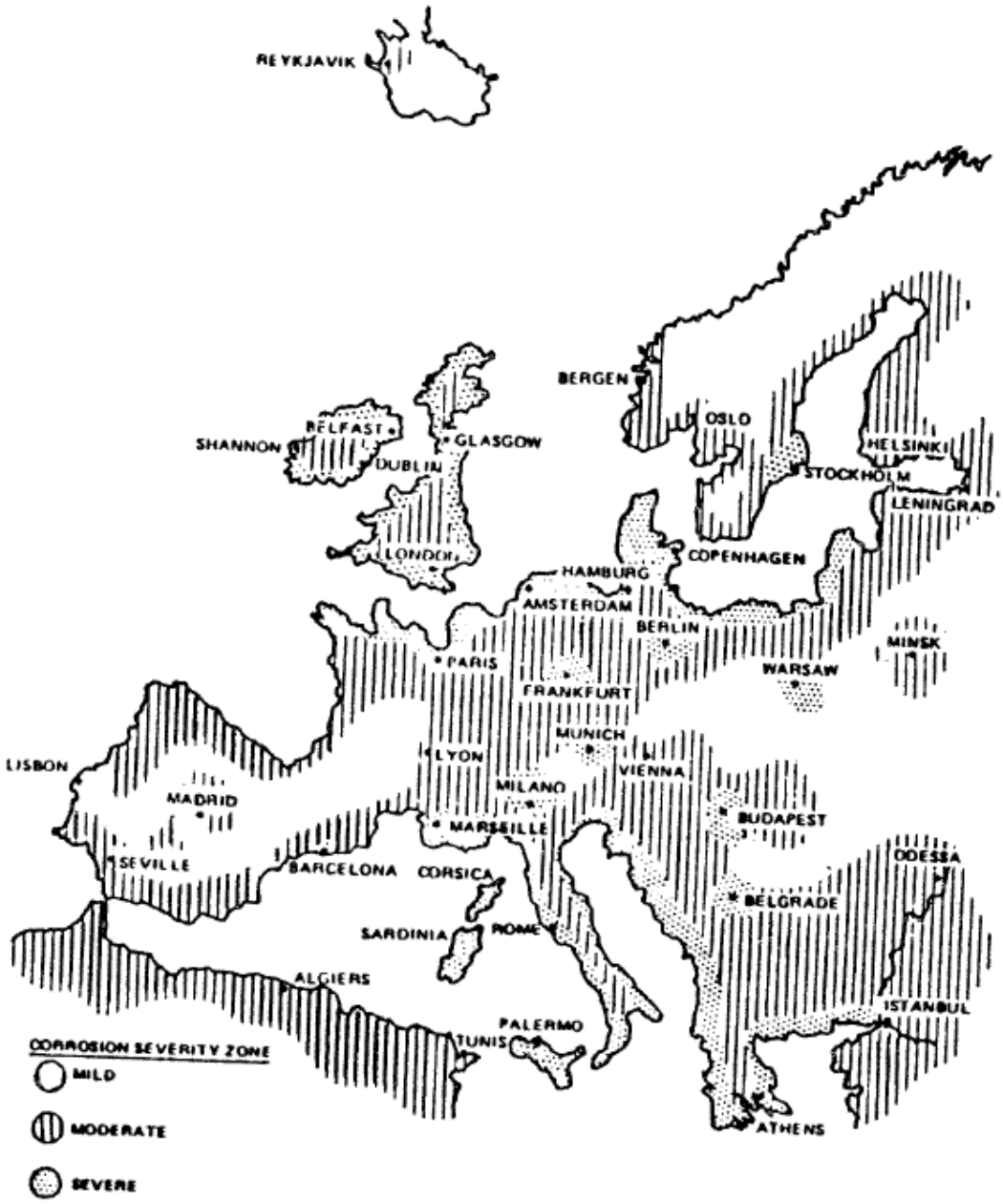


Figure 4-20: Europe and Asia Minor Corrosion Severity Map



Recommendations:

Information extracted from PW617F and PW515E Engine Maintenance Manuals Section 05-20-00:

The manual section contains information related to the **scheduled maintenance checks** which include the following Compressor Wash Schedules:

Phenom 100		
CONDITION	INSPECTION/TASK	INTERVAL
Continually salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-807)	**Daily** (increase washing frequency to suit engine condition)
Frequently salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-807)	**Weekly** (increase washing frequency to suit engine condition)
Occasionally salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-807)	**Biweekly** (increase washing frequency to suit engine condition)
Performance recovery	Performance recovery wash Ref. (Task 71-00-00-160-808)	As required to suit engine operating conditions as indicated by engine condition trend monitoring system.
NOTE: Multiple compressor washes should be performed to the extent permitted by starter operating limitations. Observe starter cooling period (Ref. Starter manufacturer's manual)		

Phenom 300		
CONDITION	INSPECTION/TASK	INTERVAL
Continually salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-805).	**Daily** (increase washing frequency to suit engine condition)
Frequently salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-805).	**Weekly** (increase washing frequency to suit engine condition)
Occasionally salt-laden operating environment	Desalination wash Ref. (Task 71-00-00-160-805).	**Monthly** (increase washing frequency to suit engine condition)
Performance recovery	Performance recovery wash Ref. (Task 71-00-00-160-805).	As required to suit engine operating conditions as indicated by engine condition trend monitoring system.
NOTE: Multiple compressor washes should be performed to the extent permitted by starter operating limitations. Observe starter cooling period - Ref. Aircraft Maintenance Manual (AMM).		

Conclusions:

(1) It is the operator's responsibility to define the required interval to do a compressor washing based in the operational profile of the airplane and operating environmental conditions.

(2) Periodic inspection of the engine externals, compressor inlet, and compressor gas path components for contamination can also be used as a basis for establishing external and internal wash requirements. Engine cleaning is basically confined to compressor desalination or performance recovery washes. However, an external wash is recommended when the engine is operated in an environment where atmospheric contamination exists.

(3) The information contained herein is highly valuable and may be used as a guideline by the operators in order to check if the locations that are currently flown and the frequency of flights represent a condition that can be classified as an “adverse environment”.

(4) Wash frequency recommendations in the PW617F-E and PW515E manuals section 05-20-00 should be adjusted to suit the engine's exposure to these adverse environmental conditions. Exposure determination of continual, frequent or occasional operation should consider factors such as time at altitude, home-base environment, destination, and storage in a sheltered, air-conditioned hangar.

(5) Example:

Let’s consider the following scenarios:

a. Airplane based in Houston flying once a week to Colorado mostly between FL 370 and 410.

b. Airplane based in Miami flying three times a week to one island in the Caribbean mostly between FL 190 and 210

- In these two specific cases, should the customer contact P&WC for recommendation, example **a** would be placed in the "Occasionally salt-laden operating environment", with a recommendation for biweekly compressor wash.
- Example **b** is definitely in the "Continually salt-laden operating environment" with a recommendation for daily wash whenever the aircraft flies such mission.

(6) With regards to **warranty**, corrosion coverage is not provided for, as this depends on factors that are beyond P&WC's control.

(7) Embraer and P&WC are ready to assist customers in establishing and optimizing an engine wash program. For further assistance, customers may contact their local Field Service Representative.