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Asbestos exposure from the overhaul of a Pratt & Whitney R2800 engine

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ABSTRACT

This study assessed the asbestos exposures of airplane piston engine mechanics while performing overhaul work on a Pratt & Whitney R2800 radial engine, with tools and practices in use since the time these engines were manufactured. Approximately 40% of the bulk samples collected during this test were found to contain chrysotile. Air samples were collected during the overhaul and were analyzed by phase contrast microscopy (PCM) and transmission electron microscopy (TEM). The average worker exposure during disassembly was 0.0272 f/ml (PCM) and ranged from 0.0013 to 0.1240 f/ml (PCM) during an average sample collection time of 188 min. The average worker exposure during reassembly was 0.0198 f/ml (PCM) and ranged from 0.0055 to 0.0913 f/ml (PCM) during an average sample collection time of 222 min. Only one worker sample (during reassembly) was found to contain asbestos at a concentration of 0.0012 f/ml (PCME). Similar results should be found in other aircraft piston engines that use metal clad and non-friable asbestos gaskets, which are the current standard in aircraft piston engines.

1. Introduction

Overhauls of aviation piston engines are performed on regulated schedules to ensure safe flights. Airplane piston engines include possible asbestos components, such as gaskets, o-rings, hose clamps, wire insulation, packings, and bushings. There have been concerns that aircraft mechanics may be at risk for an asbestos disease (Bianchi and Bianchi, 2010, 2011; Garabrant et al., 1988). Some exposure studies have been published on different aspects of aircraft maintenance (Blake et al., 2009, 2011; Mlynarek and Van Orden, 2012), as well as studies on other engine gasket work (Blake et al., 2006; Liukonen and Weir, 2005). Still, there are no studies directly related to aircraft piston engine maintenance and overhaul. Here we tested the potential asbestos exposure of mechanics during the overhaul of a Pratt & Whitney R2800 radial piston engine. Over 125,000 of these engines were manufactured between 1939 and 1970, and this model was the main airplane engine produced by Pratt & Whitney during World War II. The very complex R2800 engine and simpler aircraft piston engines in general – whether radial, in-line, or in a V orientation – have similar mechanical arrangements and use non-friable and metal-clad gaskets containing asbestos. This study reflects conditions that apply to the overhaul and service of such airplane engines, considering that the environmental conditions and work procedures in other skilled shops that specialize in the overhaul and service of aircraft piston engines are quite similar.

2. Materials and methods

2.1. Engine selection and history

The airplane piston engine type used for this study was the Pratt & Whitney R2800 model, produced from approximately 1939 until 1960. Over 125,000 of this engine type were manufactured during this time period. The R2800 model was selected for this study because it was the main airplane engine produced by Pratt & Whitney during World War II. The right to produce this engine was granted by Pratt & Whitney to other companies, including Nash, Kelvinator, Ford, and Chevrolet. The R2800 airplane piston engine used in this study had not been overhauled since 1960 and had a complete use and service series of log books. The particular engine used in this project was an R2800-30W, Serial Number P28335. The suffix denotes the type of supercharger (blower) unit attached, and this, in turn, depends on the particular aircraft that used the engine, and that aircraft's purpose. A photograph of the engine used is presented as Fig. 1.

The R2800-30W engine used in this study was accepted into service by the US Navy in 1948 and saw service until 1953 when it was stored in compliance with military specifications. These specifications included placement inside a large metal can, pressurizing the can with nitrogen, and inserting water-absorbing de-

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Fig. 1. Pratt & Whitney R2800-30W engine used in the present study. The engine is pictured at the completion of the study supported in a maintenance frame.

vices into some of the spark plug holes. The complete log books detailing the history of the engine were reviewed.

2.2. Facility

This study was conducted at Anderson Aeromotive, an established airplane piston engine service facility. This facility is certified by the Federal Aviation Administration (FAA) as an Air Agency authorized to work as a Repair Station, and operates as such under an appropriate FAA Certificate of Air Agency. The facility consists of two large buildings and adjacent outdoor storage areas located on approximately three acres in Idaho.

The facility buildings are constructed of galvanized metal walls and roof on a concrete slab. The main assembly building total volume is approximately 178,000 ft^3 (5,057 m^3). The majority of the work was done in this building. The walls and ceiling of this building are insulated with approximately two-foot wide batts of fiberglass insulation. This insulation has an aluminized coating that contains asbestos (chrysotile, 45–55% by weight), and the seams between batts are sealed with an asbestos-containing tape (chrysotile, 20–30% by weight) approximately 4" wide. Areas of the insulation and especially the tape were noted to be in poor condition. These were the only potential sources of asbestos found in the building.

There was no formal ventilation system in the assembly building. There were four large garage doors (approximately 15' W $\times$ 18' H) in this building, three in the East wall and one in the West wall. These were usually closed except to move equipment (usually for other projects) in and out and for comfort when the temperature was warm. There were three circular roof vents in the centerline of the assembly building that are manually opened in summer/warm weather, and these were closed during the time of this project. Due to these operating conditions, no attempt was made to determine the air changes per hour (ACH) in the building.

2.3. Overhaul work personnel

All work was done by, and under the supervision of, mechanics experienced in airplane piston engine overhaul and service work. The owner of the facility where this work was done has 29 years' experience working only on Pratt & Whitney airplane piston engines, and approximately half of his work experience is with the R2800 engine. The FAA certifies individuals as qualified to work on Airframes ("A" Certification) or Powerplants ("P" Certification), or both ("A&P"). The owner is a certified P mechanic, and employs two persons who are A&P certified. The owner stated that in general there is work done to two or three different R2800 engines each month, equally divided between overhauls and service work.

The owner oversaw all aspects of the overhaul and service work. The workers who performed the overhaul were all mechanics with experience in engine mechanical work of any kind ranging from 6 months to 30 years, and experience with airplane piston engines ranging from 2 months to 16 years.

2.4. General description of work and sampling

The overhaul was performed in accordance with accepted industry standards. The exception was that upon completion of the overhaul, the engine was not returned to flight readiness. The reason for this was to allow the study to be completed in a reasonable amount of time. While all engine components were reassembled, some time-consuming procedures normally part of an overhaul, principally bearing inspections, valve timing, and installation of safety wiring, were not performed. This had no effect on the assessment of airborne asbestos exposure, since no asbestos-containing part removal, replacement, or disturbance is associated with these activities.

Work of this type requires a number of specialized tools, originals or replicas were present at the facility. The work practices used were the same as those used at any point in the history of this engine, according to the owner of the facility and the two aviation experts on-site.

2.5. Overhaul

The overhaul was performed over a three week period. The first week of work on this project was spent disassembling the R2800 engine. The piston engine was stored in a large metal "can" and was removed from its can on day 1 and brought into the facility with a forklift late that day. Broadly, the disassembly process began with removal of the air foils, intake and exhaust tubes, the ignition wiring, distributors, magneto, wiring harness, and all miscellaneous exterior parts. Next, the eighteen cylinders were removed. The nose section was then separated from the power section and disassembled. The power section was then separated from the supercharger (blower) section, and disassembly of the interiors of these sections proceeded separately.

Once removed from the power section, the cylinders were disassembled separately. Part of this work was done in a separate disassembly building using a specialized machine to remove the pistons. The cylinders and their components were then returned to the assembly building for sandblasting, painting, and reassembly.

The third week of the overhaul was spent in reassembling the engine. During the second week, no sandblasting, scraping, gasket removal or other work of any sort was done to any of the disassembled components, except that all the appropriate large, exterior pieces (e.g., the housings for the nose section, power section, and supercharger) were painted. Painting of these components is a normal part of an overhaul, and presents no opportunity for asbestos exposure. Reassembly proceeded in reverse from disassembly. The interior gears, shafts, and other components of the nose, power, and supercharger (blower) sections were reinstalled, the power section was joined to the supercharger section, and the nose section was joined to the combined power-supercharger sections. The cylinders were painted and reassembled separately, then reinstalled on the engine, followed by the distributors, magneto, wiring harness, intake and exhaust tubes, the ignition wiring, the air foils, and all miscellaneous exterior parts.

2.5.1. Cylinder change

There were two cylinder changes performed. This work was done on a different R2800 engine, a B-series R2800-43 that was part of the inventory of the facility. This R2800, Serial Number FP004220, was a Pratt & Whitney engine manufactured by Ford, and was an earlier model than the one overhauled. A cylinder change is a typical "line mechanic" service task. An aircraft engine may return for overhaul with a defective cylinder, which would have to be changed before the next use.

This job consists of removing any wiring, intake or exhaust tubes, air foils, and anything else that would interfere with the cylinder removal, removing the valve rocker arm covers, removing the push rods, and removing the cylinder itself. A replacement cylinder is then installed, followed by reassembly of the above components. The gaskets on the rocker arm cover-cylinder face are changed, and also the gaskets on the push rods, intake/exhaust tubes, and any other gaskets encountered. The first cylinder change was performed on cylinder number 14 during the first week of this project, and the second was on cylinder number 6 during the second week. These cylinder changes were done at a time when it was convenient, based on the progress of the overhaul work.

2.5.2. Clutch rebuild

Two clutches from another B-series R2800 engine were rebuilt. The engine used for the overhaul did not have a mechanical clutch, but rather a hydraulic coupler (torque converter); consequently, two clutches from this alternate engine that the facility had in stock were used. Mechanical clutches often contain asbestos-containing facings.

Each of the two clutches had a high ratio and a low ratio section. The job consisted of disassembly and separation of the high and low ratio sections of both clutches and removal of the facings from each of the four sections. New facings were then installed and the clutch was reassembled.

The clutch disassembly was done during the first week. The components were left on a table in the facility away from the overhaul area. Installation of the new facings and reassembly of the clutch was done during of the second week of this project. The clutch rebuild work was done at a time when it was convenient, based on the progress of the overhaul work.

2.5.3. Ignition system rebuild

A complete engine overhaul would include inspection and rebuilding of the ignition system including the magneto, two distributors, the air pumps within the distributors, and all subcomponents. This was done on during the second week using these parts from the R2800-30W that was being overhauled. Separate personal air samples were collected from the mechanic who performed this work. Area air samples were collected in proximity to this work in conjunction with the overhaul, as were samples from the two outdoor locations.

2.6. Sample collection and analysis

2.6.1. Bulk sampling

During the overhaul work, representative bulk samples of all types of parts removed and parts installed that could have contained asbestos were collected. These samples were collected to determine whether asbestos was present in the parts, and, if present, the type and amount. Bulk samples of the engine parts were collected by placing either the entire part, or a sufficient portion of it, in a clear plastic, resealable bag. By representative parts we mean that we sampled at least one of each type, though many identical parts may have been used on the engine. For example, if a gasket was removed from a rocker box cover, that sample represented all such similar gaskets on all the rocker box covers. If a second type of gasket was found associated with the rocker box covers, this second gasket type would also be sampled. This would continue until at least one sample had been collected for all types of rocker box cover gaskets encountered.

Bulk samples were collected on various days during the overhaul work from any potential ACM present in the facility. These samples were collected to determine whether building components and/or materials could contribute to any airborne asbestos levels measured.

2.6.2. Air sampling

Air sampling was conducted to determine the airborne fiber concentrations in during the overhaul. Area sampling was conducted at four locations centered on the engine overhaul. The area samples were initiated at approximately the same time as work began, and were terminated at the end of the work day. Sampling was also conducted outside the buildings to allow comparison between outdoor and indoor fiber levels.

Personal air sampling was conducted to provide information regarding the airborne asbestos fiber exposure of persons performing the engine overhaul or service work. The personal air samples used to assess potential asbestos fiber exposure were collected in duplicate, i.e., using side-by-side personal sampling pumps and collection media (designated "left shoulder" and "right shoulder"). Both samples were analyzed.

Bystander air samples were collected on a person in the vicinity of the disassembly/assembly operation. The bystander's primary area of responsibility was to maintain paper work related to the sample collection activities of this investigation. As such, this person moved about the area, ranging from 0 to 20 ft or more from the operation. The bystander moved about the facility and came in contact with stored boxes and other materials during the course of the work day.

All filter cassettes were changed once per day at lunchtime (about 12:00 PM), and also at any significant change in work performed. In addition, filters were changed as necessary to avoid filter overloading. The timing of these changes was based on the professional judgment and experience of the field researchers regarding the nature of the activity and the associated dust generation. As a result, sample times for the individual samples varied.

Air sampling equipment adhered to the requirements of the National Institute of Occupational Safety and Health (NIOSH) Method 7400 (NIOSH, 1994a) and the Asbestos Hazard Emergency Response Act (AHERA) (USEPA, 1987). Normally personal pumps were operated at a flow rate of 2–3 liters per minute (l pm), area samples at 10 l pm. The samples were collected on cellulose ester membrane (0.8 μm pore size, 25-mm diameter) filters mounted in a new cassette with a 2-in. conductive extension.

2.6.3. Sample analytical procedures

All bulk samples were analyzed in accordance with published protocols (Perkins and Harvey, 1993).

Air samples were analyzed in accordance with NIOSH 7400 (NIOSH, 1994a) and NIOSH 7402 (NIOSH, 1994b). When asbestos was observed on a sample during the NIOSH 7402 analysis, that filter for the sample was also independently prepared and analyzed in accordance with ISO 10312 (ISO, 1995).

All analyses were conducted at the RJ Lee Group laboratory that is accredited for asbestos analysis by the National Voluntary Laboratory Accreditation Program (NVLAP) and the American Industrial Hygiene Association (AIHA). The laboratory operates under the quality guidelines established by these, and other, accrediting organizations.

2.7. Statistical analysis

PCM concentrations were calculated using the observed fiber counts with no blank filter correction. The NIOSH 7400 method detection limits are based on counting 5.5 fibers in 100 fields of view.

The asbestos concentration was determined by multiplying the PCM fiber concentration by the asbestos ratio determined in accordance with NIOSH 7402 (phase contrast equivalent, PCME). For data evaluation purposes, all samples with no asbestos structures counted were treated as 0 f/ml and not as ''less than'' a detection limit (Oehlert et al., 1995).

Standard statistical procedures, both parametric and nonparametric, were used in evaluating the data. Analysis of Variance (ANOVA, a parametric procedure) was used to evaluate differences among the observed concentrations (Neter et al., 1990). Because standard statistical approaches based on normality assumptions are apt to give poor approximations to significance levels because asbestos sample data are generally highly skewed, the Mann–Whitney U test (Daniel, 1978) (a nonparametric procedure) was also used to test for differences. Tests were also conducted to determine if there were any differences between the ''left'' and ''right'' paired samples by using linear regression, paired *t*-test and the Wilcoxon signed rank test.

3. Results

3.1. General

A total of 186 bulk samples, 124 area air samples, 122 personal air samples, and 34 blank samples were collected. Regarding phase contrast microscopy (PCM) analyses, only three of the 124 (2%) area air samples were not able to be analyzed, and only 1 of the 122 (0.8%) personal air samples was not able to be analyzed; in all four cases the filter was overloaded with dust. In addition, one outdoor area air sample was voided and not analyzed due to a power failure to the pump. Regarding transmission electron microscopy (TEM) analyses, 8 of the 124 (6%) area air samples were not able to be analyzed, and 4 of the 122 (3%) personal air samples were not able to be analyzed; in all 12 cases the filter was overloaded with dust.

3.2. Bulk samples

A total of 188 bulk samples were collected, 183 were collected from the overhaul and service work and five from the facility building materials. The results of the bulk sampling are summarized in Table 1. Of the samples associated with the overhaul and service work, 73%, or 40%, were positive for the presence of asbestos. The percent asbestos present in the samples ranged from 20–30% to 60–70%. When observed, the samples were found to contain chrysotile, except for one sample where a sealed metal o-ring component of the cylinders was opened and the material inside contained both chrysotile and amosite asbestos. It should be noted that the asbestos inside of this sealed ring can only be accessed by physical destruction of the metal component, an activity not likely to be performed by a mechanic.

There were a total of 25 (14%) bulk samples, 12 (48%) of which were positive for asbestos collected from the nose section (including the front accessory case). The power section (including the 18 cylinders) provided 48 (26%) of the bulk samples and 12 (25%) of these were positive for asbestos. The supercharger section total was 64 (35%) with 38 (59%) positive for asbestos. The ignition system components of the R2800-30W that was overhauled yielded 15 (8%) bulk samples with 1 (7%) positive for asbestos. Regarding the service work that was performed, the ignition rebuild, also performed on the R2800-30W that was overhauled, provided 11 (6%) bulk samples with none of these positive for asbestos. The cylinder change total was 14 (8%) with 4 (29%) positive for asbestos, and the clutch rebuild total was 6 (3%) with all 6 samples determined to be positive for asbestos.

Of the 6 analyses of samples associated with the facility, 2%, or 33%, were positive for the presence of asbestos. The percent asbestos present in these two samples was 20–30% and 45–55%. The type of asbestos in both of these positive samples was chrysotile.

3.3. Air samples

A summary of the results of phase contrast microscopy (PCM) analyses is presented as Table 2 organized by activity (disassembly or reassembly) and be sample type (worker, bystander, indoor and outdoor). The Table shows average concentrations for each sample type as well as the distribution of concentrations. The concentrations were nominally log-normally distributed. The average sample collection time for the workers was about 3 h (188 min).

The average PCM concentration for the worker (mechanic) was 0.0247 f/ml during disassembly and 0.0198 f/ml during re-assembly. While the average concentration was somewhat higher during disassembly, there was no statistically significant difference in PCM concentrations comparing disassembly and re-assembly (ANOVA $p = 0.26$; Mann–Whitney $p = 0.49$).

A comparison of 49 pairs of ''left'' and ''right'' samples showed there were no statistically significant differences due to cassette location (left or right) on the lapel (*t*-test $p = 0.60$; Wilcoxon signed rank test $p = 0.25$). Linear regression analysis of the samples show the left and right samples to be statistically related by ''Right = 0.966*Left'' ($p < 0.0001$). The confidence interval of the slope (0.966) was (0.864–1.068), indicating the slope is not statistically different than 1. The relative difference ((Left–Right)/Left) between the pairs averaged 0.4685 (0.3404 median).

Only 1 of 121 (0.8%) personal samples was found to contain asbestos as determined by TEM and only one chrysotile asbestos fiber was found in this sample. This sample was collected on a mechanic during the last day of engine re-assembly. The results of TEM analyses showed an average PCME concentration for all worker samples of 0.000012 asbestos f/ml. The maximum sample concentration was 0.0012 asbestos f/ml.

The average PCM concentration of the indoor area samples during disassembly was 0.0056 f/ml and during reassembly was 0.0046 f/ml. This difference was not statistically significant (ANOVA $p = 0.22$; Mann–Whitney $p = 0.41$). There were statistically significant differences in the outdoor ambient air samples (ANOVA $p = 0.0189$; Mann–Whitney $p = 0.0145$) with the disassembly air samples having a higher average concentration (0.0016 f/ml) than during the reassembly (0.0009 f/ml). This slight difference is nearly the same difference as seen in the indoor samples (0.0056–0.0046 = 0.0010 f/ml compared to 0.0016–0.0009 = 0.0007 f/ml),

Table 1
Summary of the bulk samples collected in this study.

Component	No. samples	Samples containing asbestos	Range of asbestos content
Overhaul: ignition System	15	1	25–35% Chrysotile
Overhaul: nose section	25	12	20–70% Chrysotile
Overhaul: power section	12	3	30–50% Chrysotile
Overhaul: cylinders	36	9	20–50% Chrysotile; 25–35% chrysotile and 20–30% amosite
Overhaul: supercharger section	64	38	20–55% Chrysotile
Service: clutch rebuild	6	6	25–35% Chrysotile
Service: cylinder change	14	4	25–50% Chrysotile
Service: ignition rebuild	11	0	None detected

Table 2
Summary of task-based air samples, phase contrast microscopy f/ml.

Location	Number[a]	Average sample time, (min)	Median detection limit	Geometric mean concentration	Mean concentration	Standard deviation	Percentile distribution				
							10	25	50	75	90
Disassembly											
Worker	59	188	0.0067 (15)[b]	0.0151	0.0247	0.0272	0.0049	0.0078	0.0155	0.0283	0.0695
Bystander	10	248	0.0056 (1)	0.0233	0.0276	0.0144	0.0097	0.0182	0.0284	0.0310	0.0486
Indoor	49	254	0.0010 (5)	0.0045	0.0056	0.0040	0.0018	0.0031	0.0043	0.0069	0.0130
Outdoor	18	305	0.0009 (3)	0.0014	0.0016	0.0008	0.0006	0.0013	0.0015	0.0019	0.0027
Re-assembly											
Worker	47	222	0.0056 (5)	0.0166	0.0198	0.0145	0.0085	0.0109	0.0163	0.0225	0.0370
Bystander	10	365	0.0042 (0)	0.0230	0.0250	0.0107	0.0115	0.0169	0.0273	0.0305	0.0399
Indoor	30	284	0.0009 (0)	0.0040	0.0046	0.0026	0.0020	0.0026	0.0041	0.0058	0.0083
Outdoor	10	291	0.0009 (8)	–	0.0009	0.0007	0.0002	0.0003	0.0008	0.0011	0.0020

[a] Voided samples and background samples not included in the count.
[b] Number of samples below detection limit.

Table 3
Summary of task-based personal air samples for selected operations, phase contrast microscopy f/ml.

Location	Number	Average sample time, (min)	Median detection limit	Geometric mean concentration	Mean concentration	Range
Clutch rebuild	3	196	0.0065 (0)[a]	0.0156	0.0157	0.0129–0.0179
Cylinder change	2	146	0.0133 (0)	0.0113	0.0141	0.0057–0.0226
Ignition system	2	224	0.0062 (0)	0.0181	0.0181	0.0176–0.0187
Cut gasket	1	54	0.0247 (0)	0.0427	0.0427	

[a] Number of samples below detection limit.

suggesting that the ambient air is one factor in the higher indoor air sample concentration during disassembly.

As with the personal samples, detection of asbestos fibers by TEM was very rare in the area samples. Only 5 of 79 (6.3%) indoor area samples contained asbestos with a total of five chrysotile asbestos fibers were found in these samples. In these five instances the samplers were not found in the immediate vicinity of the work area, and the resulting concentrations were extremely low. The results of TEM analyses showed an average PCME concentration of 0.000028 asbestos f/ml. The maximum PCME sample concentration was 0.0011 asbestos f/ml from a sample collected during the first day of disassembly. The five samples that were positive for asbestos by NIOSH Method 7402 were further analyzed using International Standards Organization (ISO) Method 10312. One of the indoor area samples positive for asbestos by NIOSH Method 7402 could not be analyzed by the ISO method because of damaged grids. Of the four that were analyzed, only one asbestos fiber was found in one sample. That fiber was determined to be chrysotile and less than 5 μm in length.

3.3.1. Task-based personal samples

Table 3 shows the data for the personal samples collected during selected tasks. While limited in the number of samples, all of these tasks resulted in average concentrations below 0.05 f/ml. TEM analyses of these samples detected no asbestos fibers.

4. Discussion

This study suggests that the disturbance of asbestos-containing gaskets, o-rings, and other types of seals, while performing either overhaul or service work to an airplane piston engine, produces very few airborne fibers, and that virtually none of these aerosolized fibers is asbestos. Six samples of a total of 246 personal and area air samples contained a total of six chrysotile asbestos fibers. All other airborne asbestos fiber concentrations as measured by TEM were below the analytical limit of detection for all the personal and area air samples collected.

Although this engine was stored in a sealed can in a desert for more than fifty years, there was oil present on the exterior and inside. Also, oil flowed or dripped from most parts removed during the disassembly. Consequently, the persons performing the work were dirty/oily virtually the entire time. Overhaul or service work on an engine that was on, or recently removed from, an airplane is likely to be considerably oilier, and the aviation experts on-site reported that they have observed this to be true. There was no visible airborne dust created by the overhaul or service work. No airborne dust was observed at any point in the teardown or rebuild, with the exception of the sandblasting of cylinders and pistons (which occurred in a hood in a separate room), and painting cylinders (due to paint booth malfunction).

According to the owner, the only dusty task in this type of work is sandblasting. At the beginning of a job all exterior parts are oily or have greasy dirt on them, and all interior parts are oily. In addition, as occurred during this project, during rebuild or part replacement the parts being installed are usually coated with an assembly oil to facilitate the work.

The owner and the two aviation experts stated that this engine was typical in regard to the amount of grease and dirt on the exterior, the oiliness of the work, and the lack of dust produced. The environmental conditions at this facility were similar to those at other service shops when these engines were in wide service.

During this project, removal of the gaskets, seals, o-ring, and similar items was observed to be done by hand. Occasionally, bladed-tools used to assist in loosening such items. Powered grinders, powered wire brushes and other powered tools were not used to remove gaskets and seals or any other items. This was unnecessary because all or almost all gaskets came off by hand or with simple tools. In addition, the mechanics reported that using a grinder or other powered tool to remove a gasket could potentially damage the metal seating surface below the gasket, and that using powered tools for this purpose was not part of approved protocol. The two aviation experts on site concurred that there was not a need nor a practice to use powered grinders or powered wire brushes to remove gaskets, seals, o-ring, and similar items.

Overall, the results of bulk sampling showed that various gaskets, o-ring, seals, and similar parts associated with airplane piston engines can contain asbestos, that the type of asbestos found is primarily chrysotile, and that these asbestos-containing parts are used in all sections of the engine. One metal clad gasket from the cylinder change was found to contain both chrysotile and amosite. When removed or replaced, these asbestos-containing parts were in a non-friable condition. The owner and the workers reported that in general such parts were easily removed - usually by hand or with a knife, and this was observed to be true in this study.

The average asbestos fiber concentrations for all personal and all indoor area samples as measured by TEM were approximately 0.00001 f/ml. This value corresponds to what is considered to be ambient rural asbestos levels by the Health Effects Institute-Asbestos Research (HEI-AR, 1991) and the Agency for Toxic Substances and Disease Registry (ATSDR, 2001).

Only one personal sample was found to contain asbestos. The other five samples that contained asbestos were indoor area samples. None of these area samples were collected in close proximity to the work being done and no gradient of airborne asbestos from the work location to the indoor area samplers was observed. Asbestos in bulk form was found in the building insulation covering and the tape between the insulation seams. There was a substantial amount of this bulk building insulation present – it covered the entire ceiling and some of the walls – and areas of this insulation and tape were in poor condition.

This study assessed the asbestos exposures of airplane piston engine mechanics while performing an overhaul and service work to a Pratt & Whitney R2800 radial aircraft engine, using tools, work practices, and environmental conditions similar to those used since the time this engine was manufactured. While this study is limited to one engine, the results can be realistically extended to other R 2800 engines that are virtually clones of each other, and are in general agreement with other published studies of engine overhauls. Aircraft piston engines use asbestos-containing, non-friable gaskets and metal clad gaskets, regardless of their geometric arrangement (radial, in-line, or V-shaped). Moreover, when removed, such gaskets are coated in oil and are not dry, which suppresses fiber release. This study reasonably suggests that during overhauls or service work on airplane piston engines at customary environmental conditions, the asbestos exposures of mechanics and bystanders are the same or less than ambient background levels, several orders of magnitude below OSHA exposure regulations, both current and historic.

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This study was supported by Pratt & Whitney, which has participated in asbestos product litigation. The authors have also participated in asbestos product litigation.

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