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NOISE MEASUREMENTS DATA ANALYSIS AND CONTROL OF MI-2 HELICOPTER AIRCRAFT

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Abstract. *This paper deals with the noise measurements in decibel, A weighting, (dBA) and suggest means to reduce its effect on the workers for a military trainer helicopter aircraft. The measurements have been carried out using the Impulsive Precision Sound Level Meter, B&K 2209. The aircraft is located at the air academy, (Misurata city) at the maintenance workshop. The workers, Pilots, students, engineers, and others were exposed to hazardous noise level during the day and night. Noise level was measured at two engine speeds, (57±3% and 84.5% of maximum engine speed), with one aircraft operating on the ground, and at different radial distances, up to 8 meter from the nose of the aircraft along the aircraft centre line, zero angle. Noise measurements data have been collected at different distances around the aircraft and analysed to obtain the effective noise levels in dBA around the aircraft. The permissible exposure time in (hours) of the workers at different distances around the aircraft have been pointed out and presented on the noise level contours according to the noise limits specified and classified in the A, weighted sound levels in the Occupational Safety and Health Act, OSHA of the United State of America; the Environmental Protection Agency, EPA; Canadian Centre for Occupational Health and Safety, CCOHS and the American Speech-Language-Hearing Association, ASHA for the comfort and safety of the workers. The results showed that the highest noise level is found at the nose of the aircraft at zero angle and lowest is at the tail of the aircraft at 180 degree. All effective noise level in dBA of both engine speeds with the permissible exposure time at different locations around the MI-2 aircraft for the safety and comfort of the workers were plotted as contours and presented in the full paper as well as some suggestions to reduce the effect of the noise on the workers.*

1 INTRODUCTION

Every year, approximately 30 million people in the United States only are occupationally exposed to hazardous noise. Noise-related hearing loss has been listed as one of the most prevalent occupational health concerns in the United States for more than 25 years. Thousands of workers every year suffer from preventable hearing loss due to high workplace noise levels. Since 2004, the Bureau of Labor Statistics, BLS has reported that nearly 125,000 workers have suffered significant, permanent hearing loss. In 2009 alone, BLS reported more than 21,000 hearing loss cases, [1].

Exposure to high levels of noise can cause permanent hearing loss. Neither surgery nor a hearing aid can help correct this type of hearing loss. Short term exposure to loud noise can also cause a temporary change in hearing (your ears may feel stuffed up) or a ringing in your ears (tinnitus). These short-term problems may go away within a few minutes or hours after leaving the noisy area. However, repeated exposures to loud noise can lead to permanent tinnitus and/or hearing loss, [1].

The word noise carries the meaning of unwanted sound, disgust or discomfort. The noise pollution is generally refers to unwanted or harmful noise, such that automobiles, airplanes, or industrial workplaces, [2]. Unlike other forms of pollution, noise does not remain long in the environment. However, its effects are immediate as mentioned above. The loud noise can also cause other physical problems such as high blood pressure, increased or abnormal heart rate, insomnia or difficulty sleeping, [2-3].

Aircraft noise is one form of noise pollution produced by aircraft or its components, during various phases of a flight or on the ground while parked such as auxiliary power units, while taxiing, on run-up from propeller and jet exhaust. Most people who work with or near the aircraft have soundproof ear plugs, which prevent them from the deafening noise of the plane. However, people who reside near the airports or places where aircraft are serviced or repaired have to bear the brunt of aircraft noise. They are the victims of aircraft noise pollution and their suffering has no solutions. It is disturbing people because of several different factors. First, the sound may include a combination of low frequency rumble and higher-pitched from jet engines, the throbbing of helicopters, or the steady, annoying buzz of small aircraft. Second, unlike highway noise, which is generally constant and may fade into the background, each aircraft overflight is likely to be recognized as a distinct event, calling attention to itself when it interrupts speech or some other activity, [4].

The aviation noise became a public issue in the late 1960s, governments have enacted legislative controls. Aircraft designers, manufacturers, and operators have developed quieter aircraft and better operating procedures. Researchers and doctors have talked about the harmful effects of heavy noise pollution for many years but government's bodies are just not taking it seriously. Many countries have authorized programs to insulate homes and airports and imposed night flying restrictions from 11 p.m. to 7 a.m. to reduce noise exposure at night as examples: at Heathrow, Gatwick and Stansted airports in the UK, and Frankfurt airport in Germany, [5-6]. Noise limits were specified in the A-weighted sound levels in the Occupational Safety and Health Act (OSHA), [1] of the United State of America and the Environmental Protection Agency (EPA), also developing noise-emission standards, determining appropriate noise levels that would not infringe on public health and welfare, [7-8].

The American Speech-Language-Hearing Association was also specified and classified the noise levels in Decibel, dB starting from the painful to the faint effect, [9].

Most of noise-control measures have focused on reducing the amplitude of the sound after it is produced. Reference [8] and [10] is working on a method of cutting down on noise at the source. His idea is to "fill in" the wake behind each rotor blade by pushing air through the trailing edges of the rotating blades. This recently became feasible with the advent of newer engines having fan blades that are larger than ever before at 1 m to 1.5 m high. The new technique is a trend toward larger and larger fan blades in engines.

The main aim of this paper was first to measure the noise level of the MI-2 helicopter aircraft in A-weighting decibel (dBA) at different conditions (engine and main rotor speeds), distances and directions on the ground during the daytime and then to control its effect on the workers. The permissible exposure time in hours, Tp is then estimated and presented as contours for the safety and comfort of the workers working at the Air Academy (also limited international airport for the city of Misurata).

2 SOUND LEVEL METER

The sound level meter is the heart of any noise measuring program. The basic elements of a typical impulse sound level meter are: microphone, a preamplifier, special weighting network, amplifier, meter, and output terminal. Three weighting networks, A, B and C are commonly incorporated in most sound level meters. These were designed to provide a response that approximate the way in which the human ear responds to the loudness of pure tones. The B-weighting is rarely used in practice. The scale of the C-weighting is essentially linear over the frequency range of the greatest interest.

The A-weighting sound level meter has found much use in noise measurement, since it correlates reasonably well with hearing damage risk in industry and with subjective annoyance for a wide category of industrial, transportation and community noise. D-weighting was found on some sound level meters for aircraft fly-over noise. The readings obtained using these networks were designated sound levels rather than sound pressure levels with the octave filter set B&K type 1613, see Figure 1. When reporting sound level readings, the weighting employed is always indicated. For example, "77 dBA" means the A-weighting sound level is 77 dB.

Figure 1: Sound Level Meter, B&K 2209

3 MI-2 HELICOPTER AIRCRAFT DESCRIPTIONS

MI-2 Helicopter aircraft was manufactured by "the Polish Aviation Industry" , Poland. The aircraft was all metallic structures. It is equiped with two seat basic training aircraft fitted with two GTD 350 engines developed with total output of 589 KW (800 HP) at the compressor turbine rotatory speed reacheing 45000 r.p.m. It was designed to train pilots in visual and instrument flying both during the day and at night and also navigation and aerial photography. It was equipped with guns, rockets.

Two GTD 350 engine was installed in the aircraft, and composed of the following sections: air intake, axial-centrifugal compressor, combustion chamber, Gas producer turbine, free power turbine, exhaust system, and gear box. The aircraft has four engine speeds, take off range, nominal range, cruising, and idling or low gas range. The noise measurement was recorded at two engine and rotor speeds, namely, idling speed (57±3% and main rotor 50±10%) and cruise speed (84.5% and main rotor 84%) of the maximum engine speed and main rotor. The maximum takeoff weight of the aircraft was 3550 Kg and empty weight was 2372 Kg. the overall length of the aircraft was 17.42 m including both main and tail rotors, 14.558 m main rotor diameter and overall height, 4.526 m including tail rotor as shown in Figure 2 and presented in [11].

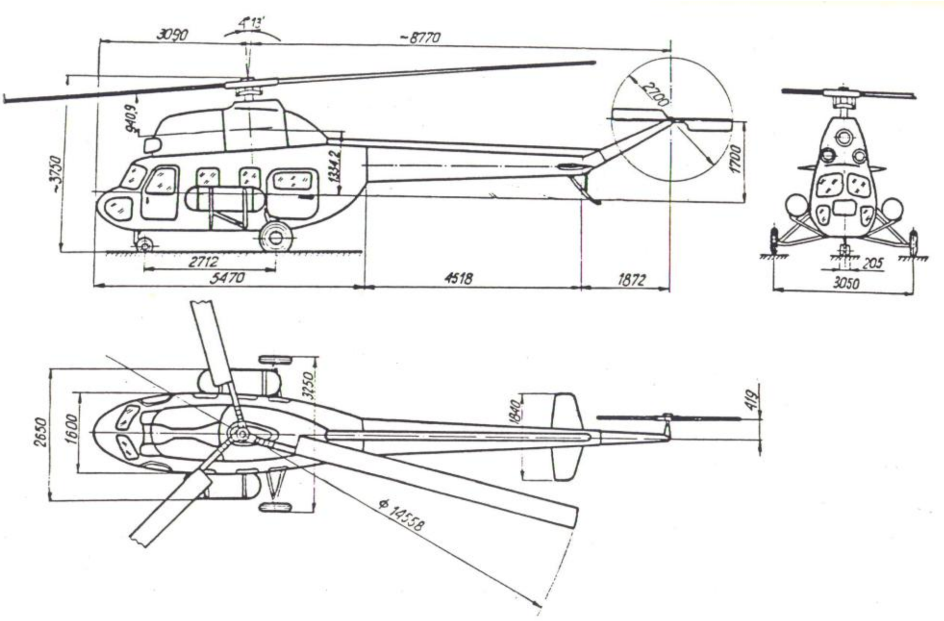

Figure 2: MI-2 Helicopter aircraft side views (dimensions in mm).

3.1 Aircraft Station

The station of MI-2 helicopter aircraft was not large and there were many aircraft on this station. Large hangar and class rooms made from concrete with steel was used for aircraft maintenance and teaching student pilots. These were located close to the station by about 5 meters. Workers includes, Pilots, students, engineers and technicians and others were working in the stations and the hanger for 8 hours daily continuous and may be in the night.

4 NOISE MEASUREMENTS AND RESULTS

Noise equipment was calibrated and noise measurements were taken at different locations for one aircraft in operation. Noise level was measured at the workers ear position using the A weighting network in many positions at 57±3% r.p.m, engine idling speed and 50±10% r.p.m main rotor, and at cruise engine speed of 84.5% r.p.m and 84% r.p.m of main rotor.

Sample of the noise level readings at different locations, orientations and conditions were presented in Tables (1-7), whereas the effective decibels were calculated for different locations and presented in Tables (8-10) for completeness using Figures (3-4) and the approach presented in [3-4]. The effective noise levels in dBA of both engine speeds with the permissible exposure time in hours, Tp at different locations were plotted in Figures (5-6) as contours around the MI-2 helicopter aircraft for the safety and comfort of the workers.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Idling speed 57±3% r.p.m and main rotor 50±10%	31.5	68
	63	67
	125	67
	250	67
	500	67
	1000	66
	2000	65
	4000	67
	8000	67
	16000	66
	31500	65

Table 1: Noise level at 5 m from tail rotor

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Idling speed 57±3% r.p.m and main rotor 50±10%	31.5	66
	63	64
	125	63
	250	63
	500	64
	1000	63
	2000	63
	4000	64
	8000	63
	16000	65
	31500	65

Table 2: Noise level at 8 m from tail rotor.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Idling speed 57±3% r.p.m and main rotor 50±10%	31.5	74
	63	73
	125	74
	250	75
	500	72
	1000	75
	2000	73
	4000	73
	8000	75
	16000	75
	31500	74

Table 3: Noise level at 8 m from aircraft right side.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Idling speed 57±3% r.p.m and main rotor 50±10%	31.5	73
	63	73
	125	73
	250	73
	500	73
	1000	72
	2000	73
	4000	73
	8000	72
	16000	72
	31500	73

Table 4: Noise level at 8 m from aircraft left side.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Cruise speed 84.5% r.p.m and main rotor 84%	31.5	90
	63	91
	125	92
	250	91
	500	91
	1000	91
	2000	91
	4000	91
	8000	91
	16000	91
	31500	91

Table 5: Noise level at 5 m from aircraft nose.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Cruise speed 84.5% r.p.m and main rotor 84%	31.5	90
	63	88
	125	88
	250	88
	500	88
	1000	88
	2000	89
	4000	89
	8000	88
	16000	89
	31500	89

Table 6: Noise level at 8 m from aircraft nose.

Engine speed	Octave band centre frequency (Hz)	Noise level (dBA)
Cruise speed 84.5% r.p.m and main rotor 84%	31.5	83
	63	83
	125	83
	250	83
	500	83
	1000	83
	2000	83
	4000	83
	8000	83
	16000	83
	31500	83

Table 7: Noise level at 8 m from aircraft left side.

	Octave Band Centre frequency (Hz)										
	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
Band level (dBA)	87	89	89	87	89	87	87	90	90	87	89
Step 1*	91.1		90.1		90.1		91.8		91.8		89
Step 2*	94.1				94.1				93.65		
Step 3*	94.1				96.9						
Combined	98.75 dBA										

Table 8: Effective noise in (dBA) at 5 m from the aircraft nose at 57±3% and 50±10% r.p.m.

	Octave Band Centre frequency (Hz)										
	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
Band level (dBA)	84	85	86	85	87	87	88	88	87	83	82
Step 1*	87.5		88.5		90		91		88.45		82
Step 2*	91				93.5				89.35		
Step 3*	91				94.9						
Combined	96.4 dBA										

Table 9: Effective noise in (dBA) at 8 m from the aircraft nose at 57±3% and 50±10% r.p.m.

	Octave Band Centre frequency (Hz)										
	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
Band level (dBA)	83	83	83	83	83	83	83	83	83	83	83
Step 1*	86		86		86		86		86		83
Step 2*	89				89				87.8		
Step 3*	89				91.45						
Combined	93.45 dBA										

Table 10: Effective noise in (dBA) at 8 m from the left side of the aircraft nose at 84.5% and 84% r.p.m.

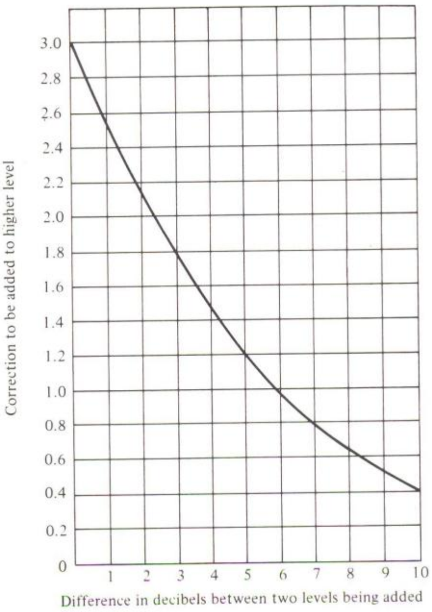

Figure 3: Adding levels, [3]

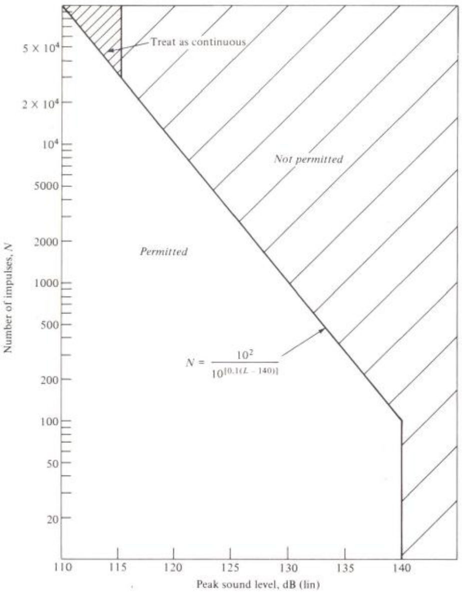

Figure 4: Allowed exposure for continuous level, [3].

5 DISCUSSION OF RESULTS

Tables (1-10) refer to the samples of measured noise level and effective noise of the MI-2 helicopter aircraft at 57±3% r.p.m, engine idling speed and 50±10% r.p.m main rotor speed and at 84.5% cruise engine speed and 84% main rotor. The workers are exposed to this speed most of the time on the ground. From the above tables, it can be seen that the noise level changes at different locations and directions. This was may be due to the uneven burning in the combustion chamber and to the wind velocity and the speed of the main rotor and turbine may change slightly because tolerances are provided. However, this variation should not affect the analysis. The noise level at various points near the sides of the aircraft was almost the same due to the conditions of both compressor, turbine and main rotor was not changed at a particular speed and steady state was everywhere.

Figures (5-6) show the coordinates of r and ϴ, which was the relation between the radial distance, r from the aircraft engine, which is the distance between the aircraft engine and the moving observer, and the angle ϴ from the line of the fuselage reference. At the aircraft nose, $ϴ = 0^o$ and at the aircraft tail, $ϴ = 180^o$. Permissible exposure time is computed using Figure 4, and [3].

It can be seen from Figure (5), when the radial distance is 5 m from the aircraft nose and in the line of the fuselage, $ϴ = 0^o$, the noise level was 98.75 dBA, as the angle increased on both sides of the MI-2 helicopter aircraft to $ϴ = 90^o$, the noise level reduces being lower and much lower at the aircraft tail, $ϴ = 180^o$. Similar variations of noise level was observed at a distance of 8 m, the noise level in dBA was 96.40 at $ϴ = 0^o$, 84.25 dBA and 83.10 dBA at $ϴ = 90^o$ on the right and left side of the aircraft respectively and the noise level was 79.40 at $ϴ = 180^o$. The lowest noise level occurs at aircraft tail, ϴ = 180 degree at both engine speeds.

Figure 6 shows a similar noise level variations in dBA at 84.5% engine speed and 84% main rotor compared with the idling speed shown in Figure 5.

The permissible exposure time, Tp was shown at each noise level for safety and comfort of the worker around the MI-2 helicopter aircraft. The obtained noise readings were only for one aircraft in operation and this will be changed accordingly if more than one aircraft in operation and as a result, the noise level will be higher and the permitted time will less. The higher the engine speed, the higher noise level, see Figures (5-6).

It was found from the calculations of pressure that as the distance increase from 5 m to 8 m at idling engine speed, 57±3% r.p.m and main rotor at 50±10%, the pressure near the ear reduces to about 76 % at $\Theta = 0^o$, see Table 11 for more details.

Radial distance , r (m)	Angle, ϴ degree	Pressure variation, in (%) for 57±3% and main rotor 50±10% r.p.m.	Pressure variation, in (%) for 84.5% and main rotor 84% r.p.m.
5	0	76%	75%
8	0		
5	90	73%	79%
8	90		
5	180	74%	69%
8	180		

Table 11: Pressure variations in (%) at both engine and main rotor speeds.

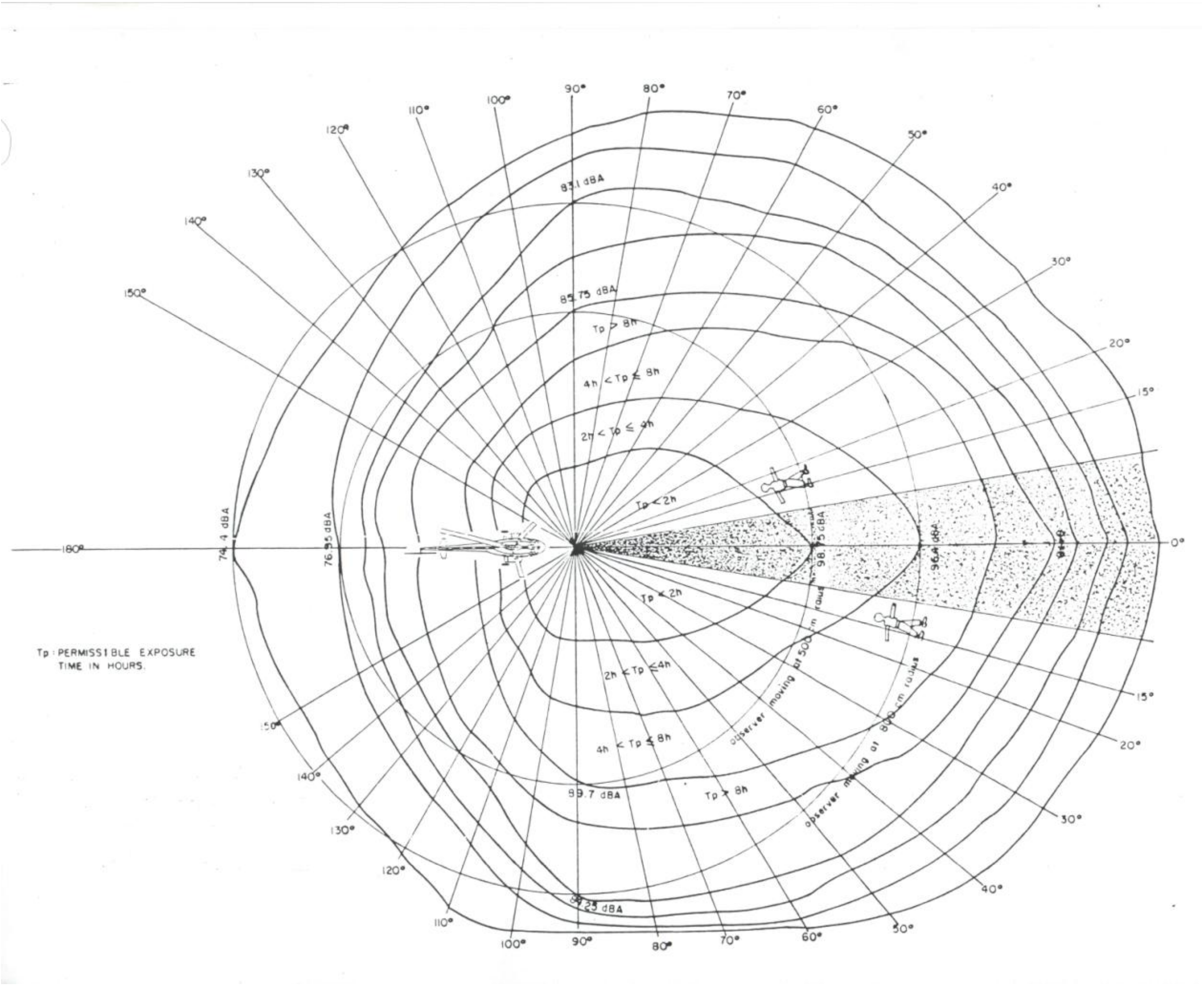

Figure 5: Noise field from MI-2 Helicopter aircraft at engine speed, 57±3% r.p.m and main rotor at 50±10% r.p.m, the curved lines represent equal noise level.

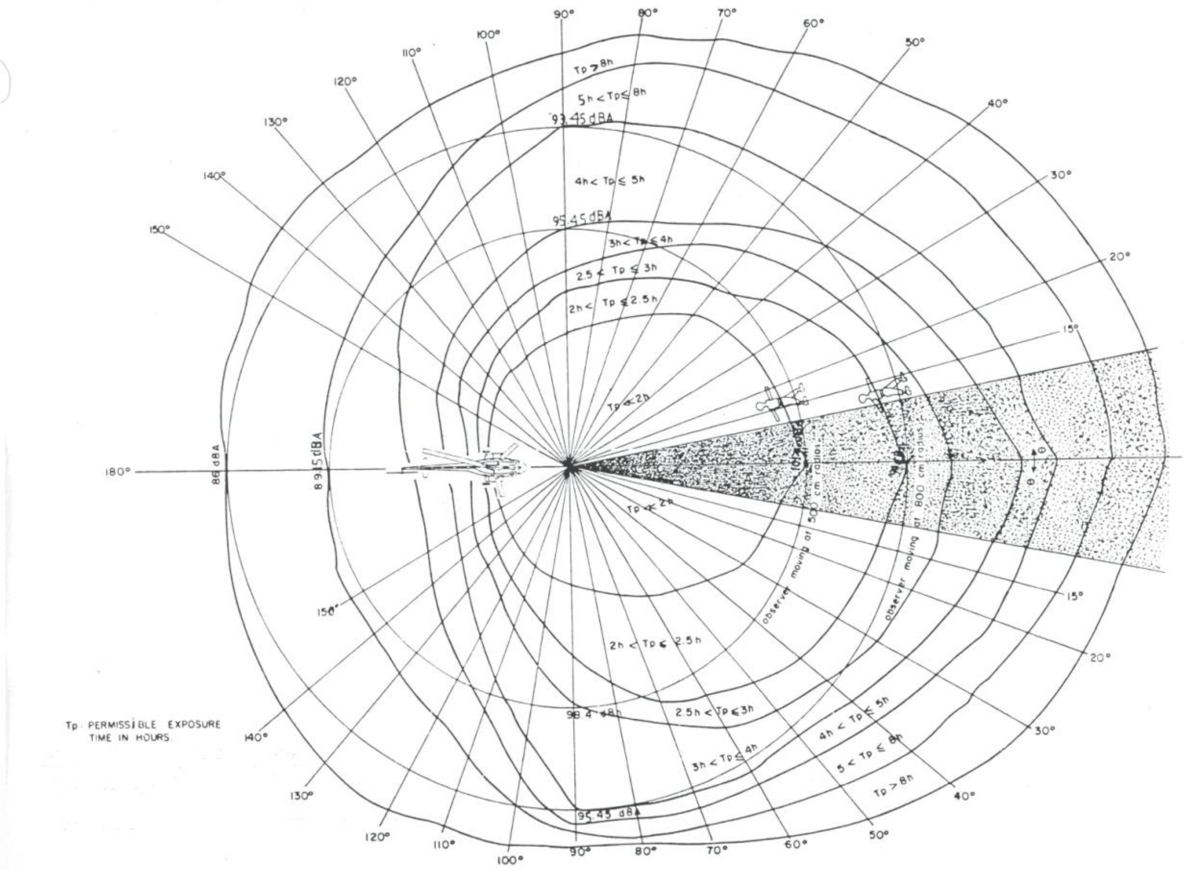

Figure 6: Noise field from MI-2 Helicopter aircraft at engine speed, 84.5% r.p.m and main rotor at 84% r.p.m, the curved lines represent equal noise level.

6 SUGGESTIONS AND IMPROVEMENTS

When there are more than one aircraft in operation in the station, the noise level will increase and will cause annoyance, hearing loss, speech interference to others. There were class rooms for the students and technicians close to the aircraft station.

Some suggestions regarding the reduction of noise effect on the workers around the aircraft and in the building to improve the comfort and safety to the workers are presented. These suggestions should minimize the effect of noise on the workers in a low cost without changing the noise source, aircraft jet engine, (expensive), which are listed below:

1. The distance between the workshop (hanger and class rooms) and the aircraft station (noise source) should be increased and also by putting or growing belts of trees between the noise source and the receivers as barriers.
2. Area of the aircraft station should be increased to make large space between one aircraft and another.
3. Providing proper design of the building structures, in which the sound absorbent materials are used, such as sound walls and curtains, (sound proof rooms) for the workers.
4. Enclose or isolate the noise source in the case of engine tests in the workshop.
5. Operating noise source during shifts when fewer workers were exposed whenever possible.
6. Limiting the amount of permitted exposure time, Tp in hours to the higher noise levels for the workers as shown in Figures (5-6).

7. Providing all the accessories for eliminating higher noise level such as headphones, earmuffs and plugs to the workers.
8. Replacement of the old engine or aircraft with new lower noise levels one, which is very expensive and may be avoided as in this case.

7 CONCLUSIONS

Noise measurements and suggest means to control its effect on the workers was carried out successfully on MI-2 helicopter aircraft in Air Academy, Misurata, when one aircraft was on operation at two engine speeds, namely idling speed at 57±3% r.p.m and 50±10% r.p.m main rotor and cruise speed at 84.5% and 84% main rotor of the maximum engine speeds. Permissible exposure time to noise, Tp in (hours) was obtained using the graph provided by OSHA. All workers must not exceeded this time for their health and safety.

The higher noise level was found at zero angle (aircraft nose), all workers should be avoided this location and stick to the allowable exposure time for stay, whereas The lowest noise was found at the aircraft tail, $\Theta = 180^o$ from the fuselage centre line.

Some suggestions were addressed in this work to reduce the effect of noise level in the outdoor and indoor areas for the comfort and safety of the workers and must be taken into considerations.

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