ENCLOSURE (B) 33

ENGINE TEST METHODS FOR AVIATION FUELS AT OFUNA

by

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LIST OF TABLES AND ILLUSTRATIONS

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I. INTRODUCTION

An engine test plant was installed at the First Naval Fuel Depot in 1942 in order to examine the performance properties of fuels and lubricants.

The three sections concerning aviation fuel and lubricants are as follows: The First section includes the single cylinder engine testing plant and aircraft engine bench testing plant to test aviation fuels and lubricants; The Third section is equipped with physical and analytical laboratories for lubricants. The Fourth section includes the C.F.R. testing engine to determine the octane number and the chemical analytical fuel laboratory.

The engine testing plant had two main objectives, one to discover new and better fuels and lubricants, and the other to assist this institute in their production.

The engine testing plants were built during 1942. The first work undertaken was in relation to high octane aviation fuel, and particularly engine tests of aromatic hydrocarbons, (Enc. (B)21). As the aviation fuel supply in Japan became more critical, efforts were directed to improve the production and supply of aviation fuel, we increased lead content, (Enc. (B)24, Part II).

Extensive research programs on substitutes for gasoline were then undertaken, and on the use of alcohol as aviation fuel, (Article 3 of this series, Enc. (B)17) and "Engine Test of Pine Root Oil as the Aviation Fuel" (Article 4 of this series, Enc. (B)10).

II. DETAILED DESCRIPTION OF APPARATUS

A. Single Cylinder Engine Test

Engine structure and flow sheet apparatus are shown by the attached blue prints, Plate I(B)33-Plate IV(B)33.

1. Dimensions of engine:

Cylinder bore	140mm
Stroke	150mm
Compression ratio	7.0(variable)
Maximum RPM	3000
Maximum hp	100
Maximum boost	+700mm Hg

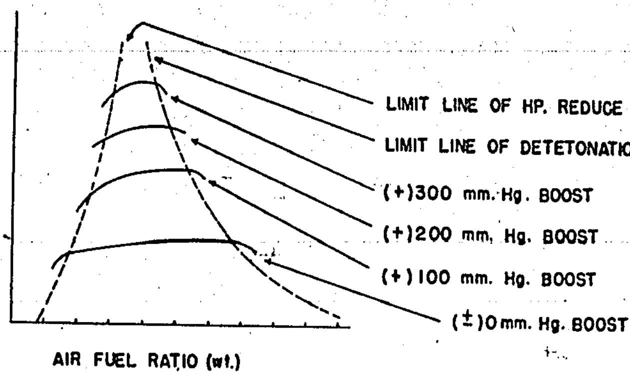
2. Methods of operation

An electric dynamometer motors the engine during the starting period and when warming up of the engine is finished the fuel supply and ignition switch are turned on. Intake air is supplied by "Enke" type blower (two blowers are connected in series) and its mass of air flow is measured by nozzle attached at the intake pipe. The fuel is injected into the intake manifold. The temperature of the inlet lubricant oil is kept 70-75°C constantly.

One operator controls both air and fuel supply and the other operator controls load by means of the electric dynamometer. Test measuring process is as follows:

At a constant speed, the intake air pressure (boost) is increased step by step (±)0, (+)100, (+)200,-----mm Hg and at each boost, fuel consumption varied, and at each fuel consumption engine operation is maintained for three minutes continuously to establish a steady operating condition for the engine.

The useful range of the air fuel ratio at each boost is tested and the maximum allowable boost and smooth running range of air fuel ratio (See Plate I(B)33.



3. Method of measuring

Detonation is judged by the cyliner temperature and the state of exhaust gas flame. During running, the engine is maintained continuously for three minutes at the same set of conditions. A constant cylinder temperature is reached after about 1-1.5 minutes if detonation does not occur.

If detonation occurs, the cylinder temperature climbs continuously, and finally increases very rapidly, accompanied by a change in the colour of the exhaust gas flame and occasional puffs of black smoke. The auto-ignition is judged by switching off the ignition spark and if the engine continues to run, it is considered that auto-ignition has occurred.

The cylinder temperature is measured by an electric thermocouple using chromel and aromel wires.

The couple wires are welded to the copper washer of the spark plug. Exhaust gas temperature is measured by the same electric thermocouple protected by stainless steel tube, the position of which is about 35mm from the cylinder exhaust port. The power output of the engine is measured by the electric dynamometer which loads the engine and controls the engine speed. The mass of the intake air is measured by a flow nozzle which is attached at the suction side of the blower. Fuel consumption is measured by a stop watch and 200cc measuring glass bottle which is connected between the fuel tank and the fuel pump. Air-fuel ratio is calculated by the above mentioned measuring data and also roughly indicated by the Cambridge Type gas analyser for exhaust gas.

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B. Full-Scale Engine Test

~~The layout of the apparatus is shown by the attached blue prints, Plate~~ V(B)33 and Plate VI(B)33. There are two means of absorbing the power in full-scale engine tests: one is air screw attached (Plate V(B)33), the other a water brake dynamometer (Froude Type)(Plate VI(B)33).

Both apparatuses can be used for a maximum of 3000 hp. The building is a sound-proof structure with a material made from hemp rags. The engine test installation attached to the air screw is mainly used for endurance test of the lubricant, while the engine attached to the dynamometer is mainly used for fuel performance tests.

The former test was not put into practice because of the shortage of supply of the aviation fuel and strict orders for saving fuel.

The operating method for the full-scale engine attached to the water brake was similar to that described for the single cylinder engine.

III. PROGRESS OF RESEARCH WORK

Performance tests with aromatic fuel were first made in December 1942 to investigate a new and high octane aviation fuel.

It was found that aviation fuel should contain less than 20% benzene (C_6H_6), otherwise detonation occurred.

Toluene showed the best performance results as aviation fuel and equaled or exceeded iso-octane. Xylene or higher aromatics i.e. solvent naphtha etc. (dry distilled oil from coal) also showed good anti-knook properties, but it was necessary to improve the fuel supply apparatus as these aromatics had poor volatility (Enc. (B)21). But the production of such aromatics was very small and they had other important uses in addition to their use as fuel. Therefore, alcohol was investigated as a substitute for gasoline.

For training plane engines (below 500 hp), alcohol blends were used. The alcohol content in aviation gasoline was increased step by step, i.e. 20%, 50%, and finally absolute alcohol was used.

The use of alcohol for training engines presented no insurmountable difficulties, but did require some shanges in carburettors and the starting and acceralation techniques.

Next, specifications of aviation fuel in order to obtain a larger amount of aviation fuel from a fixed quantity of base oil, and there was no other way to do this than to lower the specifications, that is, to enlarge the distillation range.

As a result of using low octane gasoline for training plane engines and elevation of temperature of the end point, the octane number decreased. Steps were taken to investigate the increase of tetraethyl lead content in gasoline to increase the octane number, but it was considered that this caused more contamination upon the spark plugs. The influence of increased tetraethyl lead content in aviation gasoline upon engine performance and ignition plugs, and inhibiting effects of $C_2H_4Br_2$ on the contamination due to the increased tetraethyl lead were also investigated (Enc. (B) 24).

The results showed that aviation gasoline with 0.3% (Vol.) tetraethyl lead could hot be used, and that $C_2H_4Br_2$ acted as an inhibitor preventing contamination of lead upon spark plugs, but an excess burned the plugs. Moreover, the supply of aviation fuel reached a critical stage, and there arose an urgent desire to use alcohol for the second class engines (below 1300 hp) in order to save gasoline.

The difficulties of using alcohol were its poor volatility and its low heat of combustion. The problem of low heat of combustion was solved by improvements in the fuel flow control of the carburettors.

In order to improve volatility, blends of fuel, ethyl ether acetone and gasoline were examined (Article 3 of this series, Enc. (B)17).

The effect of acetone and gasoline was good, but ethyl ether was unsatisfactory because of its preknock properties. Researches on using alcohol for high class engine was not completed. Finally, the use of pine root oil for aviation fuel was planned.

Aviation gasoline prepared by catalytic or hydrocracking of pine root oil fraction below 300°C was found to give the same engine performance as the standard aviation gasoline --91 O. N. (Article 4 of this series, Enc. (B)10).

Crude pine root oil boiling below 185°C could not be used alone, as aviation fuel, because of its poor volatility, low octane value and high tendency toward gum formation on the spark plugs, when engines were operated for long periods at low temperatures. However, when a small amount of crude pine root oil was added (20% by volume) to ethyl alcohol, the blend could be used with the same results as obtained with ethyl alcohol alone.

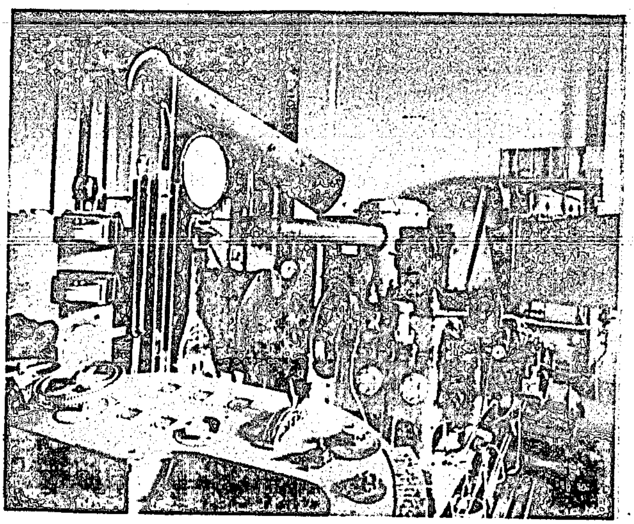


Figure 1(B)33
MONO-CYLINDER TESTING ENGINE

ENCLOSURE (B)33

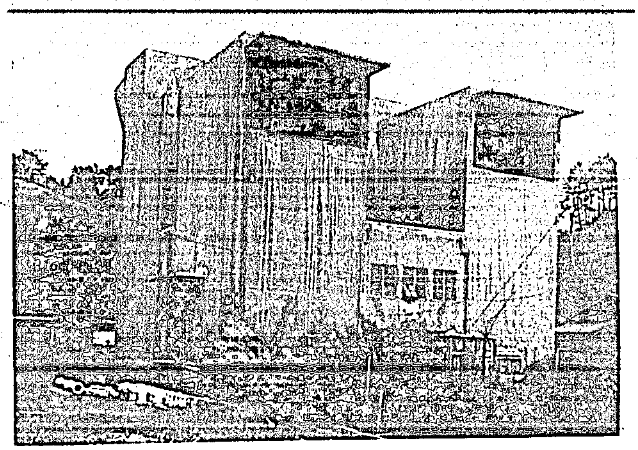


Figure 2(B)33

GENERAL VIEW OF THE
FIRST EXPERIMENTAL LABORATORY
FOR FULL SCALE ENGINE

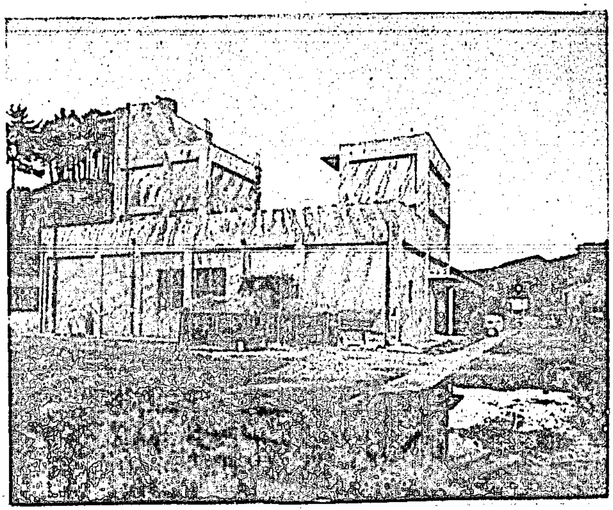


Figure 3(B)33

GENERAL VIEW OF THE
SECOND EXPERIMENTAL LABORATORY
FOR FULL SCALE ENGINE

ENCLOSURE (B)33

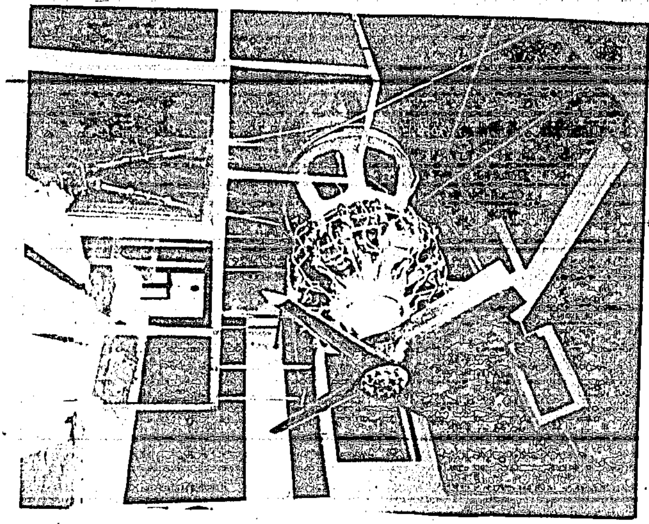


Figure 4(B)33

CLOSE UP VIEW OF TESTING SHOP
FOR FULL SCALE ENGINE

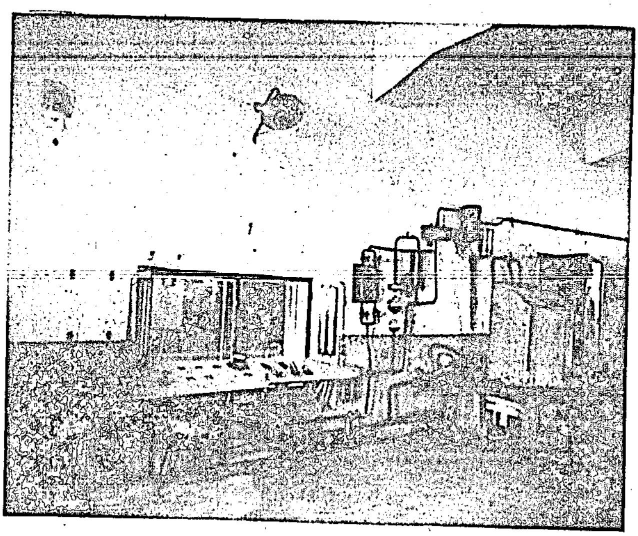
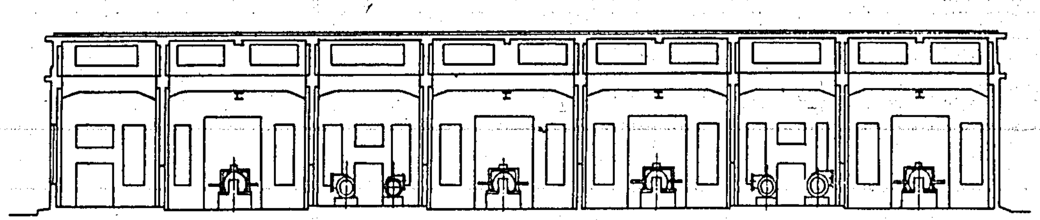
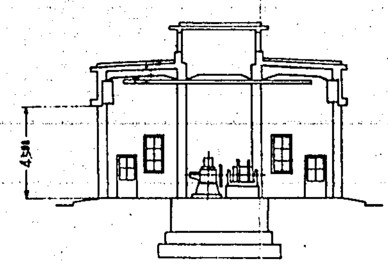
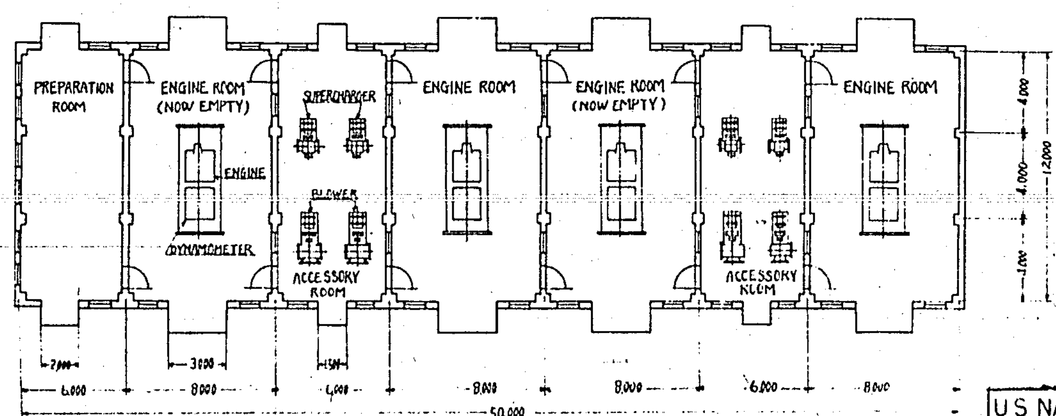


Figure 5(B)33

CLOSE UP VIEW OF THE
CONTROLLING PDATFORM

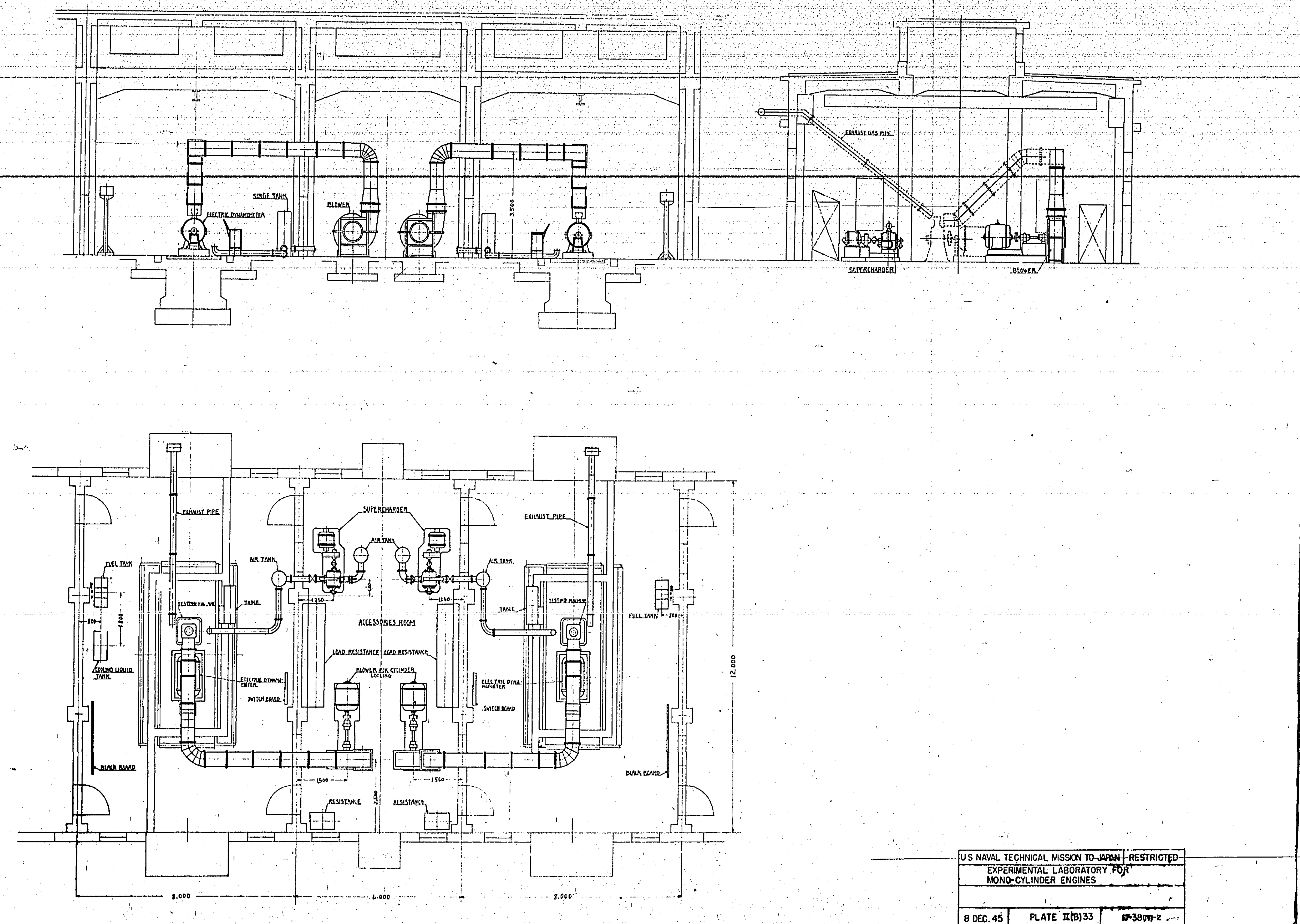




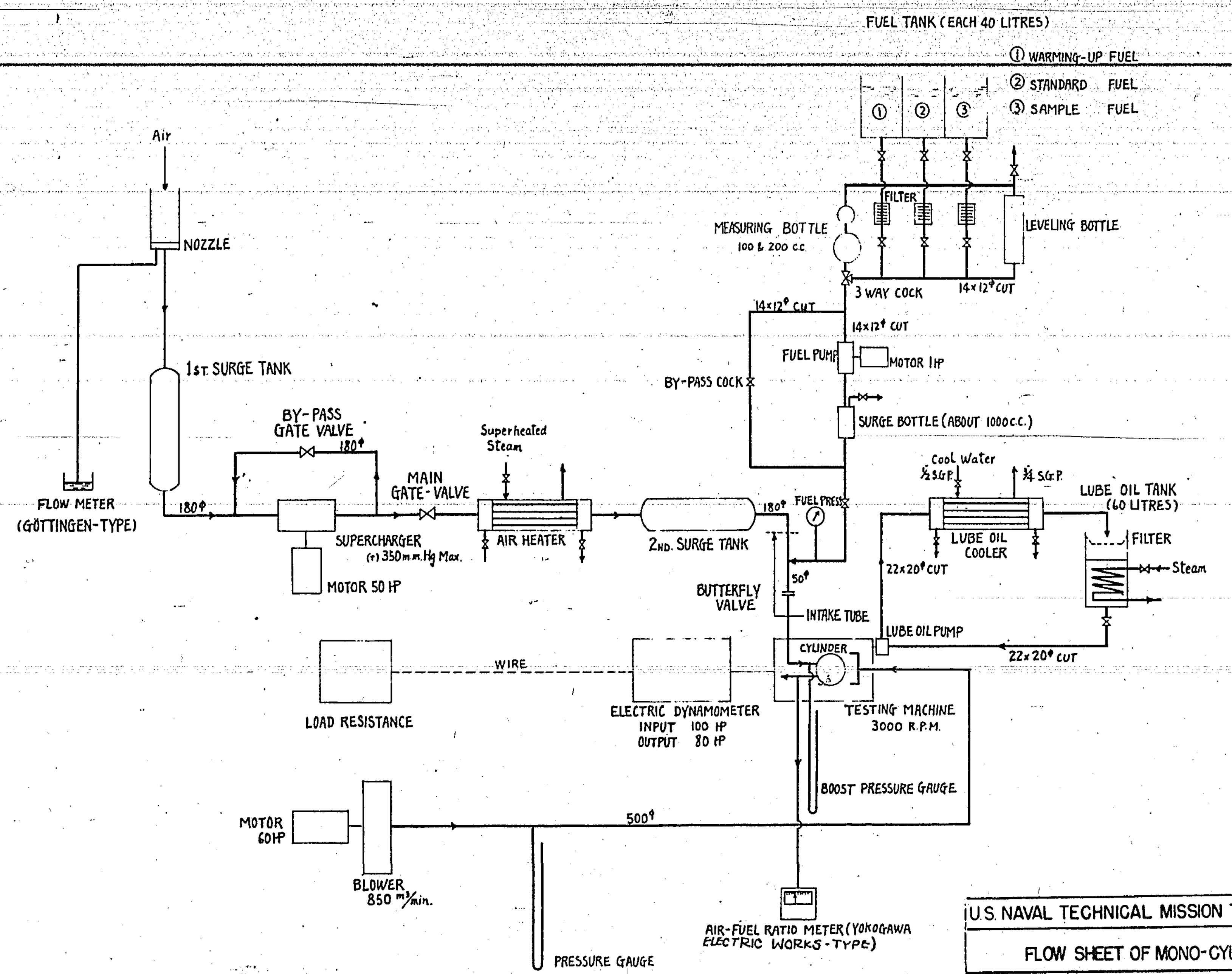


U S NAVAL TECHNICAL MISSION TO JAPAN		RESTRICTED
EXPERIMENTAL LABORATORY FOR MONO-CYLINDER ENGINES		
8 DEC 45	PLATE I (B) 33	X-38(N)-2

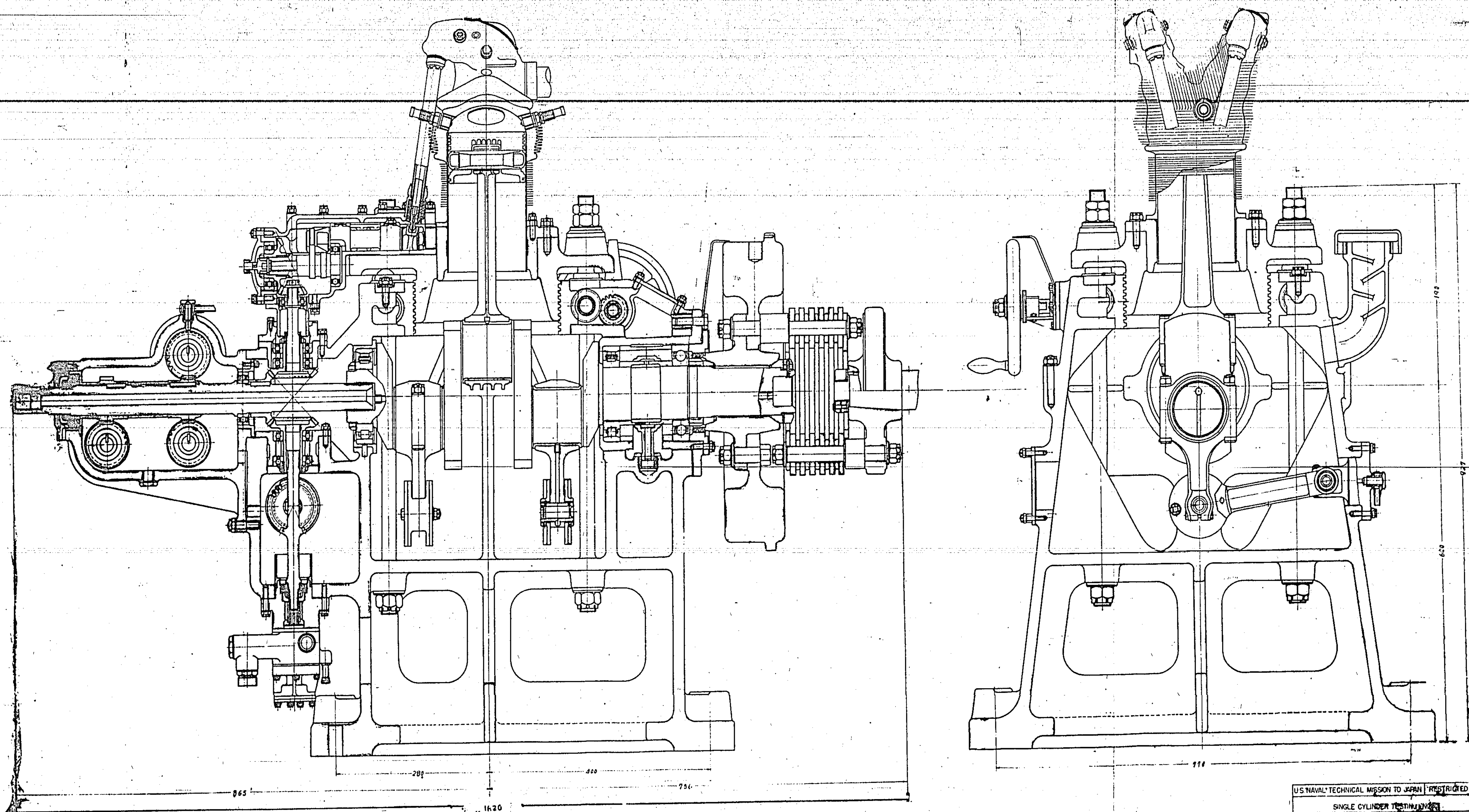
(Ser. No. 074. Enc. B-33)



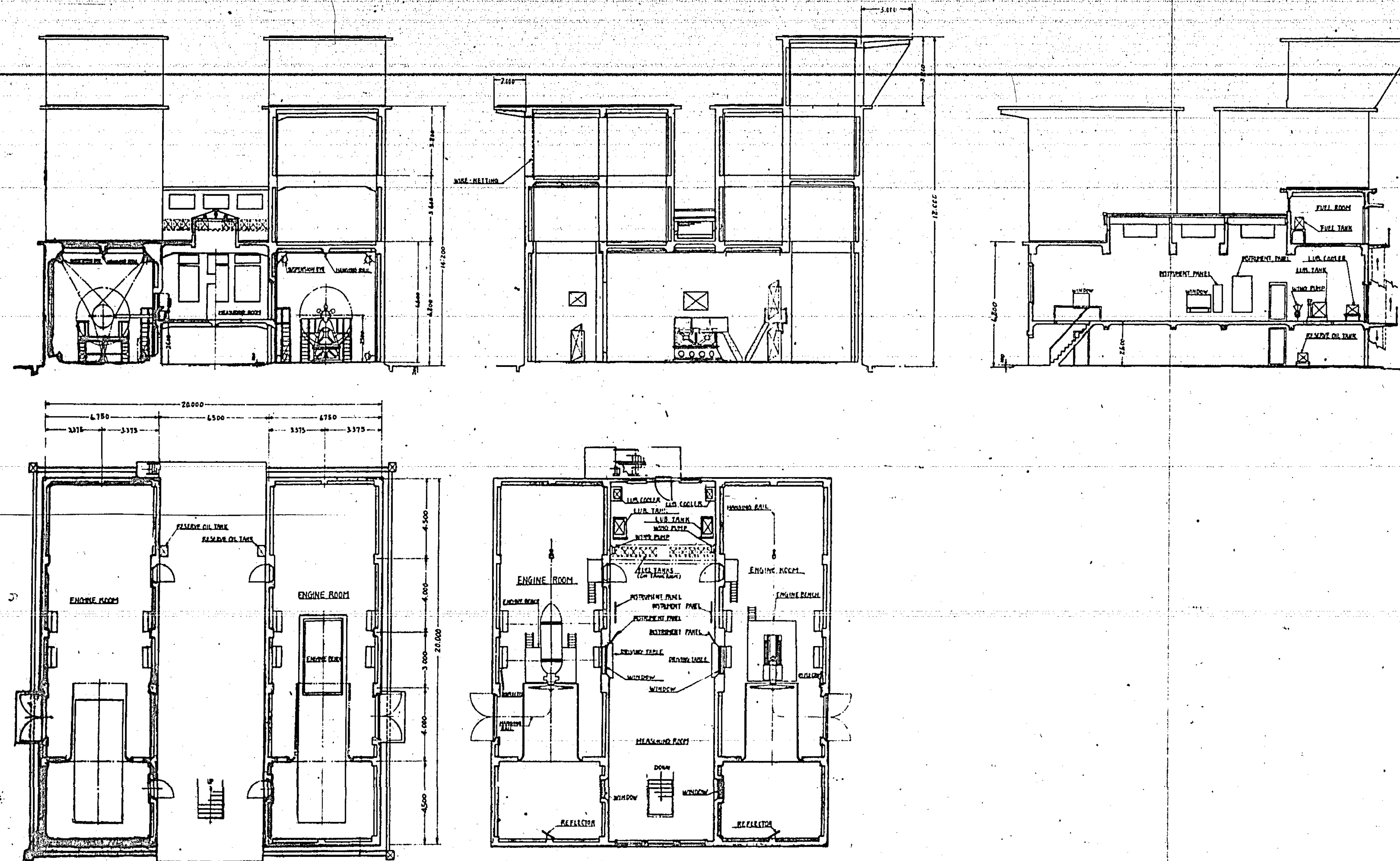
US NAVAL TECHNICAL MISSION TO JAPAN		RESTRICTED
EXPERIMENTAL LABORATORY FOR MONO-CYLINDER ENGINES		
8 DEC. 45	PLATE II(B)33	X-38(N)-2



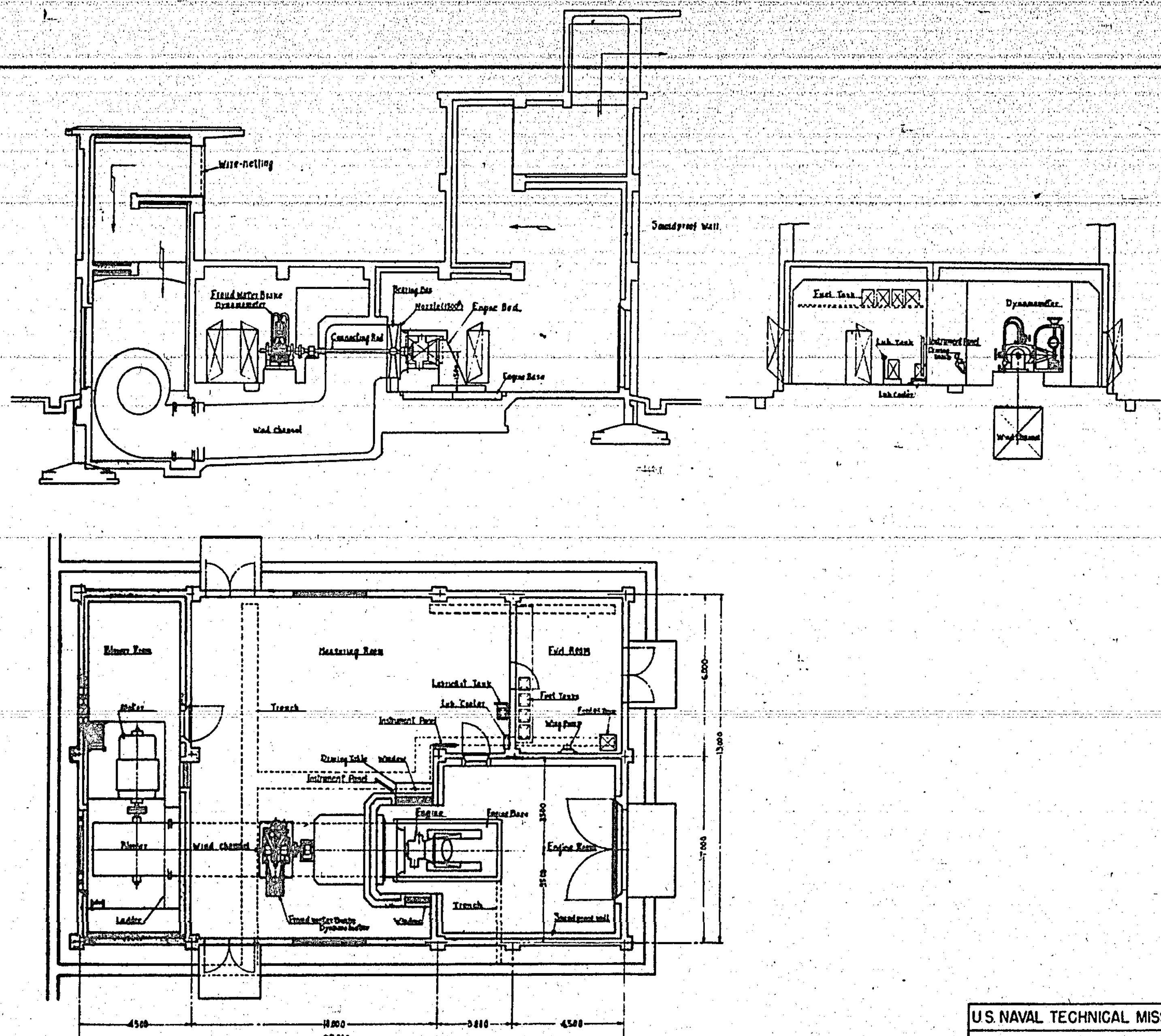
U.S. NAVAL TECHNICAL MISSION TO JAPAN	RESTRICTED
FLOW SHEET OF MONO-CYLINDER TESTING	
APPARATUS	
DEC. 5, 1945	PLATE III (B) 33 · X-38(N)-2



US NAVAL TECHNICAL MISSION TO JAPAN	RESTRICTED	
SINGLE CYLINDER TESTING ENGINE		
DEC 22, 45	PLATE IV(0)33	X-38(N)-2



US NAVAL TECHNICAL MISSION TO JAPAN		RESTRICTED
FIRST EXPERIMENTAL LABORATORY FOR		
AEROENGINES		
DEC. 8, 1945	PLATE X(B)33	X-38(N)-2



U.S. NAVAL TECHNICAL MISSION TO JAPAN	RESTRICTED
SECOND EXPERIMENTAL LABORATORY FOR AEROENGINES	
DEC. 8, 1945 — PLATE VI(B) 33	X-38(N)-2