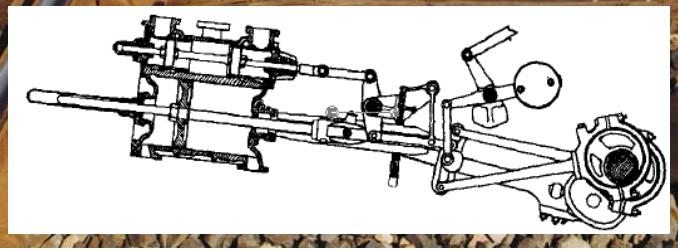
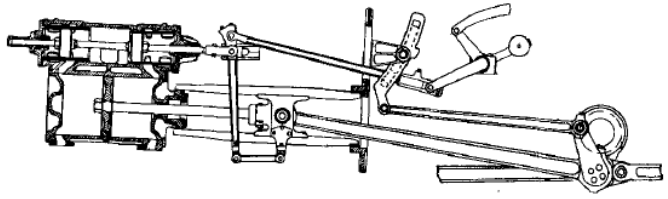
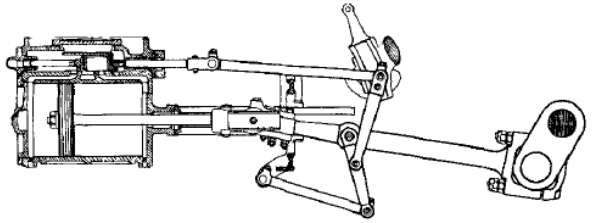
GS1

Caprotti 100 Years

- Thorough mechanical tests have been made in 1919 on a gear built to natural size and run in the shops of Officine Meccaniche Miani & Silvestri in Milan, the tests being controlled by the Italian State Railway Officials for several weeks in all the different working conditions and at all speeds, both forward and backward, and also at a speed much higher than what could be expected in service on a locomotive. The Italian State Railways being satisfied with the result of such tests, resolved to apply the new gear to one of their Consolidation engines Gr . 740, which was being built in the above shops and gave a regular order for it.



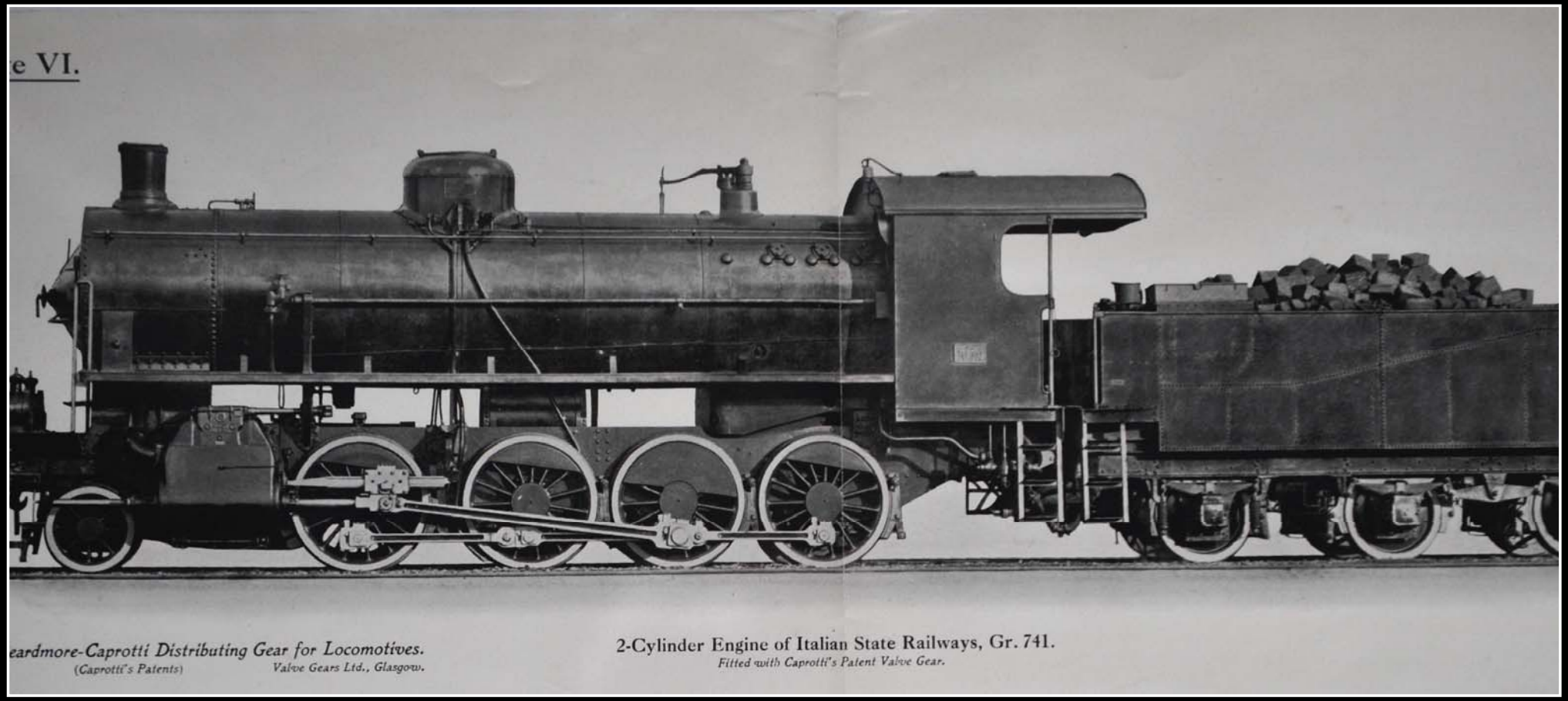




Slide 1

GS0 Beardmore A New Locomotive Distribution Gear using poppet valves
G Shirley, 2023-05-10T20:30:13.023

GS1 Paper 443 - The Evolution of Locomotive valve gears
G Shirley, 2023-05-21T10:18:35.500



First Caprotti Locomotive

GS0

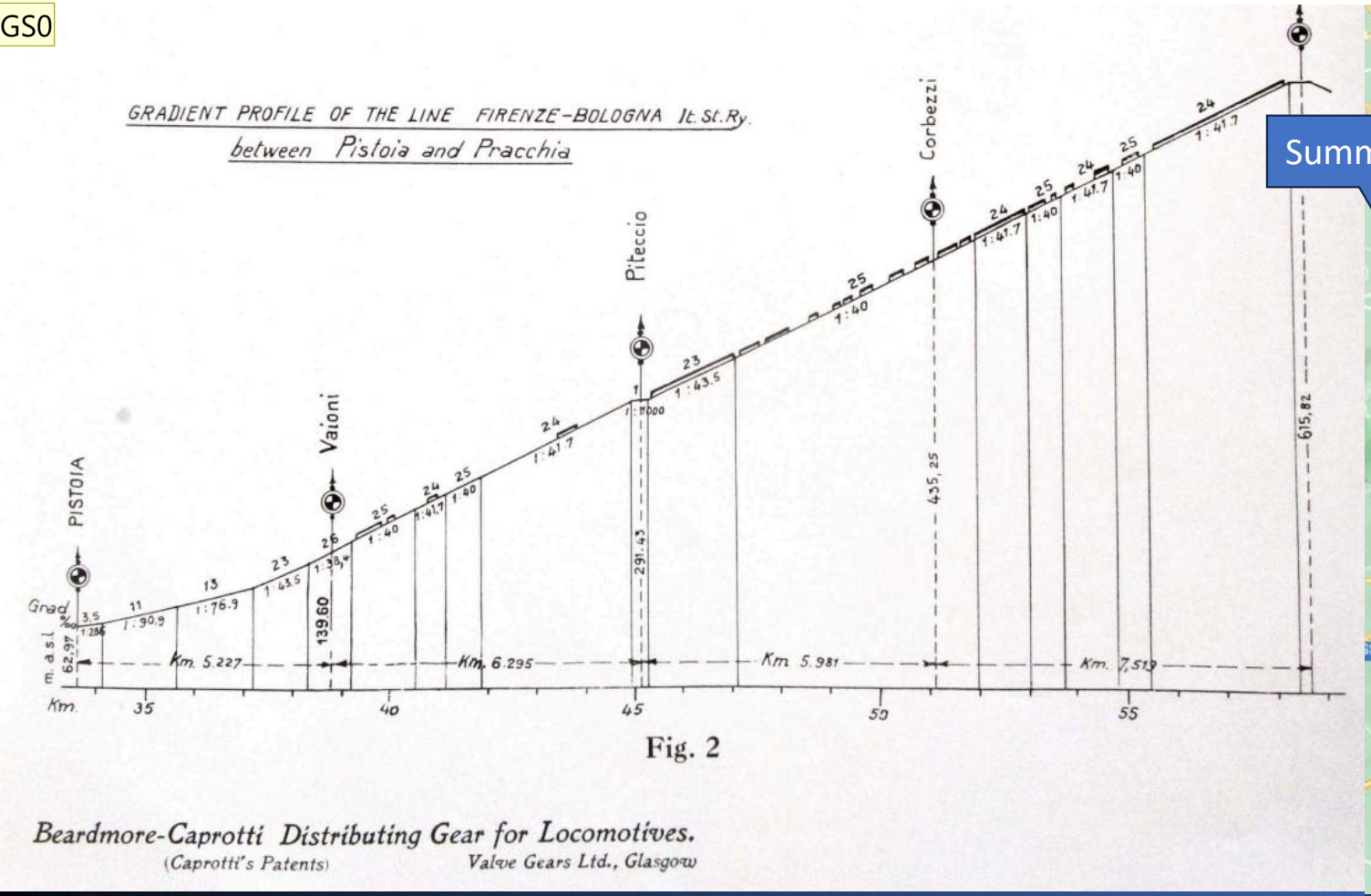
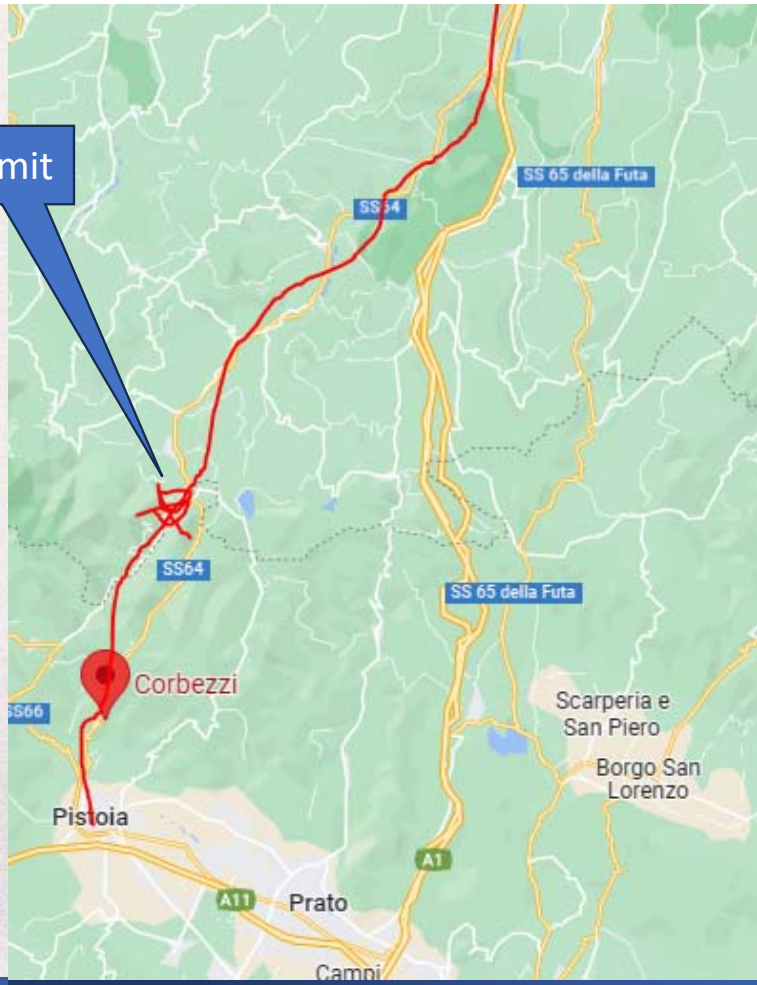


Fig. 2

Beardmore-Caprotti Distributing Gear for Locomotives.
(Caprotti's Patents) Valve Gears Ltd., Glasgow



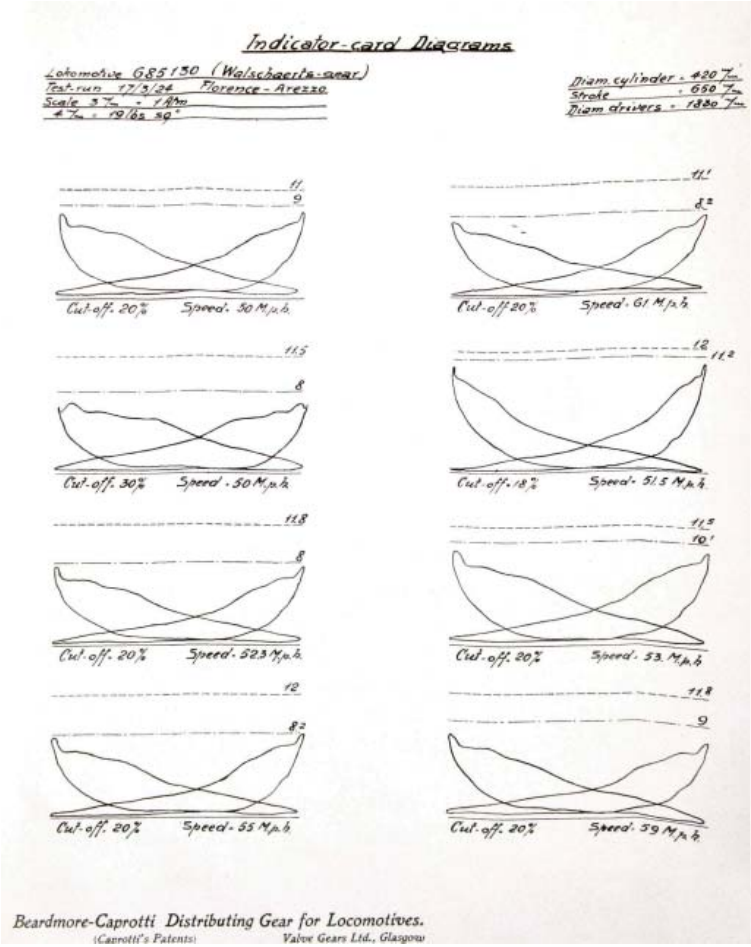
Test Track

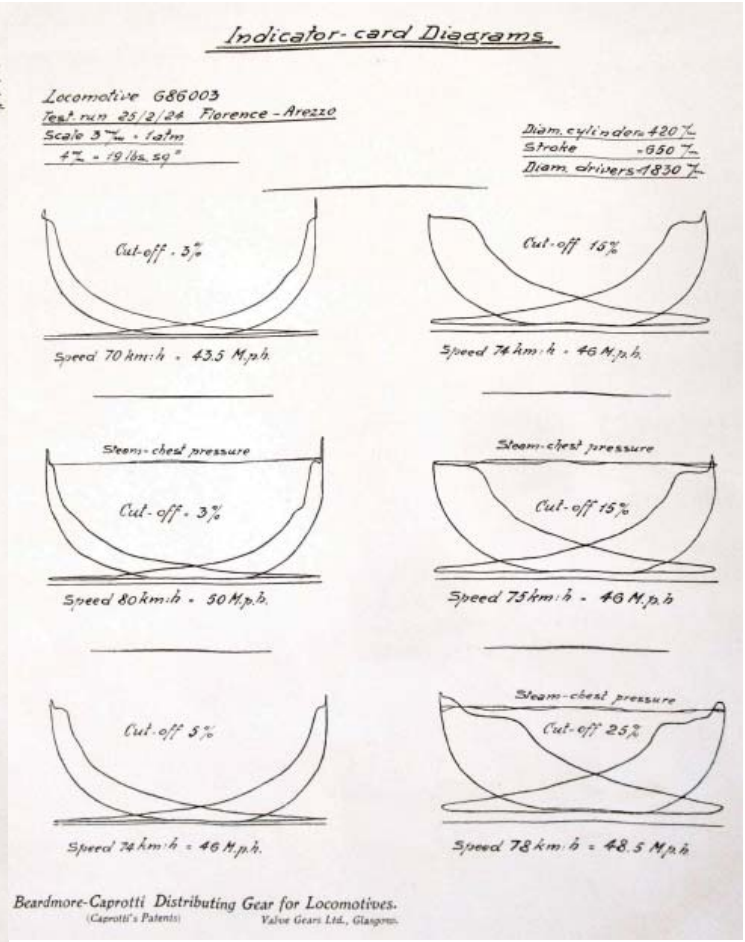
GS0 Beardmore A New Locomotive Distribution Gear using poppet valves

G Shirley, 2023-05-10T20:30:42.089

GS0

Walschaert's versus Caprotti





GS0 Beardmore A New Locomotive Distribution Gear using poppet valves

G Shirley, 2023-05-10T20:30:53.308

GS0

Expanding the Business

C-Tenderlokomotive mit Caprottisteuerung.[1]

Von Baurat Dr.-Ing. E. h. Metzeltin.

Den bisher bekannten Lokomotivventilsteuerungen, so insbesondere auch der Lentz-Ventilsteuerung, haften neben ihren Vorzügen (geringe Unterhaltungskosten, Ausnutzung höherer Überhitzung usw.) naturgemäß die Mängel aller Schwingensteuerungen an, d. h. die gegenseitige Abhängigkeit von Dehnungsbeginn und Voreinströmung einerseits und Vorausströmung und Kompressionsbeginn andererseits. Dieser Nachteil macht sich um so stärker bemerkbar, je kleiner die Füllungen werden. Darin ist auch das bei geringen Leistungen schließlich nicht zu mißbilligende Fahren des Führers mit dem Regler und nicht mit der Steuerung begründet. Bei der Schwingensteuerung verliert man im Dampfdiagramm bei kleiner Füllung zunächst, wenn auch wenig, durch die frühe Vorausströmung, um so mehr aber durch den frühen Kompressionsbeginn. Jedenfalls ist mit einer Schwingensteuerung bei weitem nicht die Völligkeit der Druckschaulinien zu erreichen, wie man sie im Dampfmaschinenbau sonst verlangt und auch mühelos erhält.

Lösungen der sich bietenden Aufgabe sind schon vor Jahrzehnten versucht, und zwar durch Trennung der Ein- und Auslaßorgane und ihre getrennte Betätigung, so z. B. in der Steuerung von Durant und Lencauchez. Eingebürgert haben sich aber solche Steuerungen nicht, weil die verwendeten Steuerorgane nicht die Vorteile boten, wie sie z. B. eine Ventilsteuerung gewähren kann. Eine richtig gebaute Ventilsteuerung muß, im Gegensatz zum Schieber, der immer ein Schmerzenskind für den Betrieb ist, mindestens ein Jahr lang ohne Nacharbeiten laufen. Den Nachweis, daß dies möglich ist, hat, wie wir später noch sehen werden, Caprotti mit einer neuen Steuerung an Lokomotiven der Italienischen Staatsbahn glänzend erbracht.

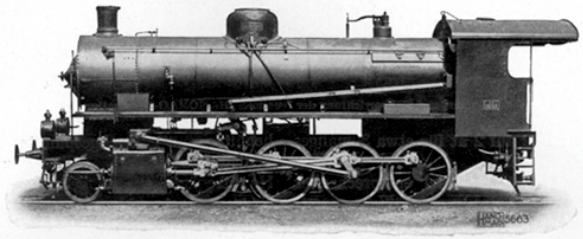


Abb. 190 Erste Lokomotive mit Caprottiventilsteuerung. 5663
Italienische Staatsbahn, Gruppe 741 im Betriebe seit Januar 1921.

Die Wirkungsweise der Caprotti-Steuerung zeigen die Abb. 190—193.

Caprotti vermeidet, wie die Abb. 190 zeigt, die äußere Schwingensteuerung vollständig. Er überträgt die Drehbewegung der Kurbel durch zwei Kegelzahngetriebe von den Gegenkurbeln der Treibachse auf eine quer über den Zylindern liegende Welle A (Abbildung 192), die also synchron mit der Treibachse umläuft. Diese beiden seitlichen Übertragungen sind inzwischen durch eine einzige von der Mitte der Treibachse ausgehende ersetzt.

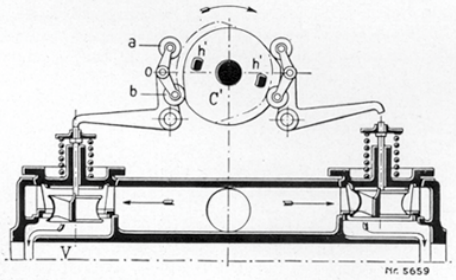


Abb. 191 Anordnung der Ventilsteuerung Caprotti. 5659
Abbildung zeigt die Bewegungsübertragung von den beiden Hubkurvenscheiben C und C' auf die Einlaßventile.

Auf der Welle A sitzen drei Hubkurven-

[1]) Literatur: Hanomag-Nachrichten 1922, S. 17, Rivista Tecnica 1921, S. 153.

GS0 Hanomag Nachrichten 131 (1924)

G Shirley, 2023-05-10T20:31:42.609

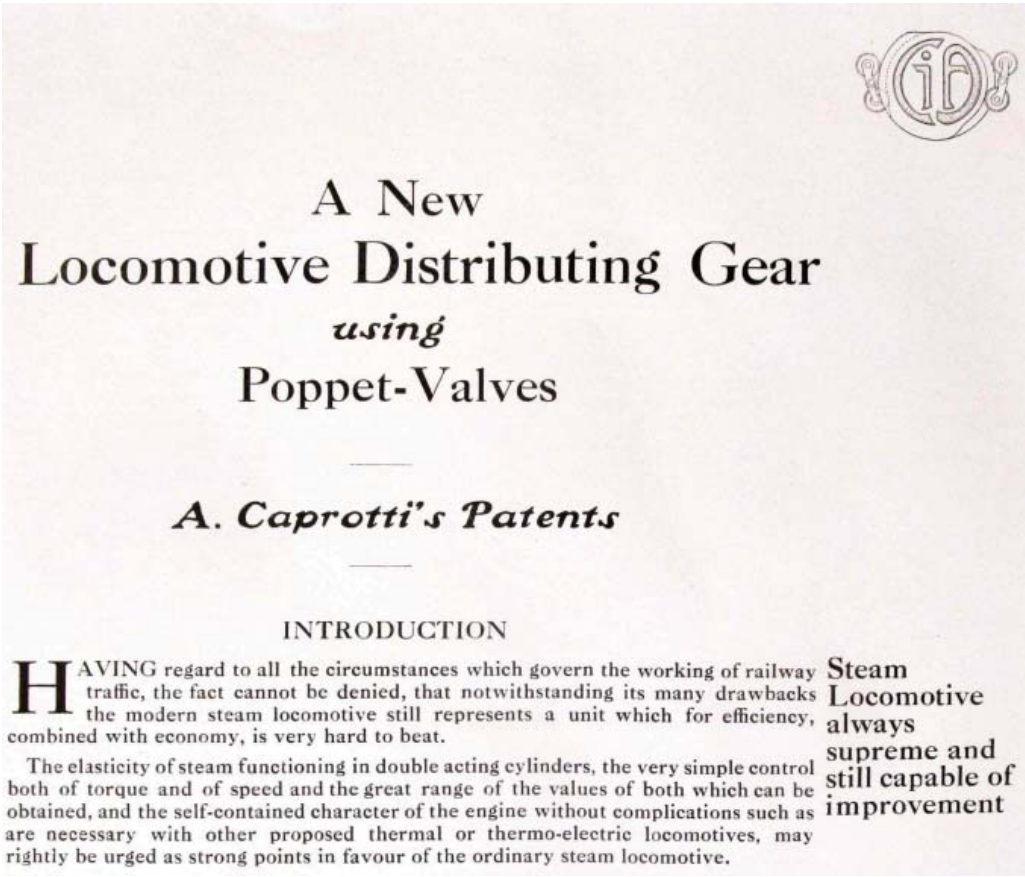
Valve Gears Ltd. (Caprotti's Patents) ◆ ◆ 50 Wellington Street, **Glasgow**

Caprotti had a family association with the Caprotti Bank with offices in Scotland. Restaurateurs & Ice cream makers of Glasgow formed a substantial contingent of Italians.

He was introduced to William Beardmore and on 22 Sept 1923 formed a company called Valve Gears Ltd.

21 Share holders, 19 Italian, 10 Restaurateurs.

Directors Pio Del Frati (Caprotti Banker), Arturo Caprotti, Lord Invernairn of Strathnain and Alexander Galbraith – both of Beardmore's.



A New
Locomotive Distributing Gear
using
Poppet-Valves

A. Caprotti's Patents

INTRODUCTION

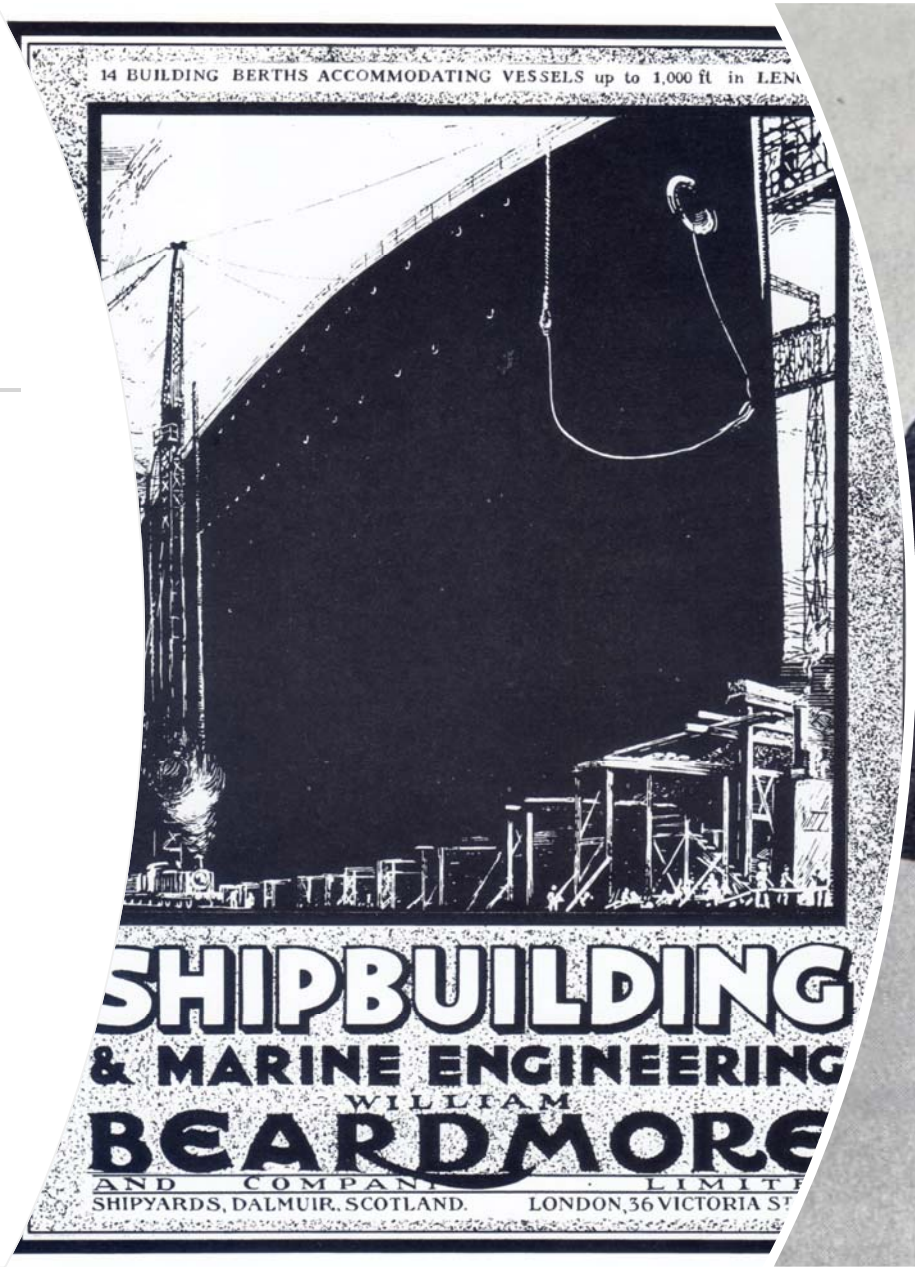
HAVING regard to all the circumstances which govern the working of railway traffic, the fact cannot be denied, that notwithstanding its many drawbacks the modern steam locomotive still represents a unit which for efficiency, combined with economy, is very hard to beat.

The elasticity of steam functioning in double acting cylinders, the very simple control both of torque and of speed and the great range of the values of both which can be obtained, and the self-contained character of the engine without complications such as are necessary with other proposed thermal or thermo-electric locomotives, may rightly be urged as strong points in favour of the ordinary steam locomotive.

Steam Locomotive always supreme and still capable of improvement

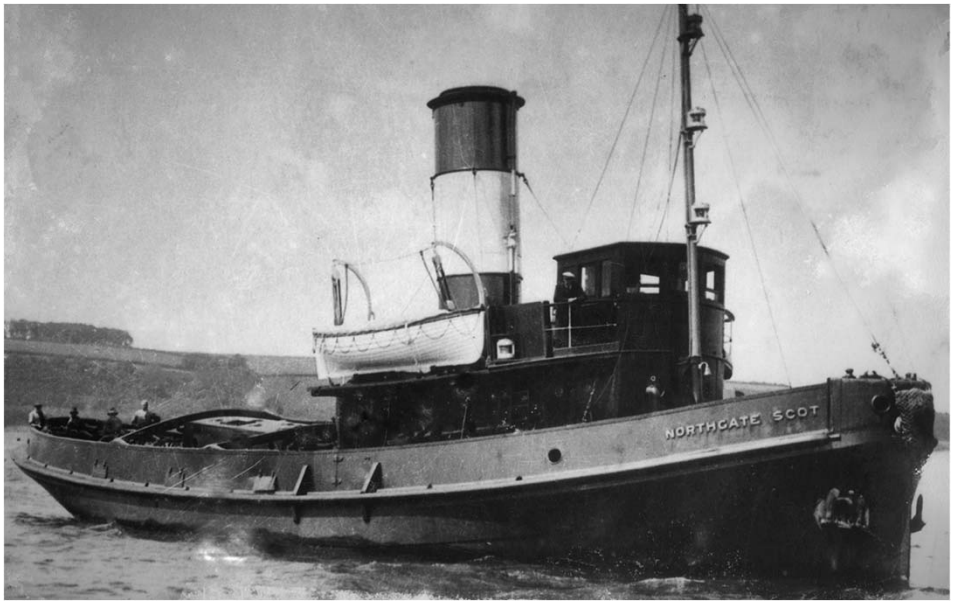
Beardmore – Innovating company

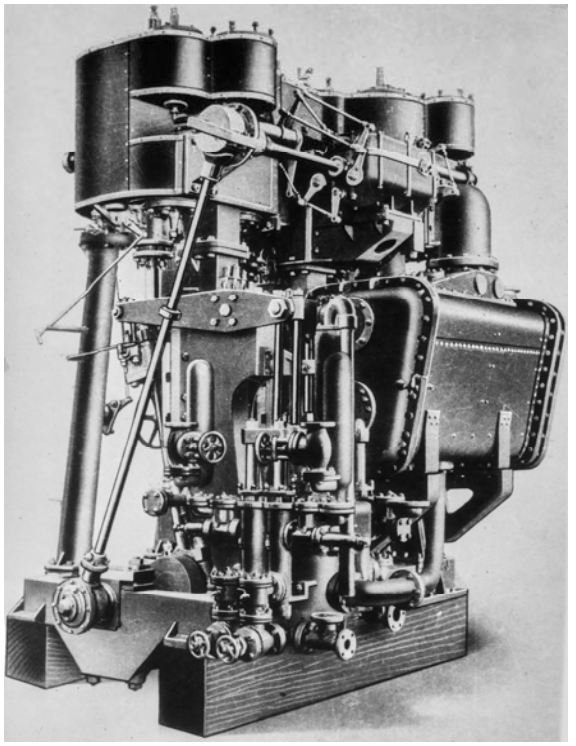
- Ships
- Guns
- Aircraft
- Airship R34
- Aero Rail cars
- Marine Engines – Steam – Supercharge Diesel - Turbine
- Locomotives



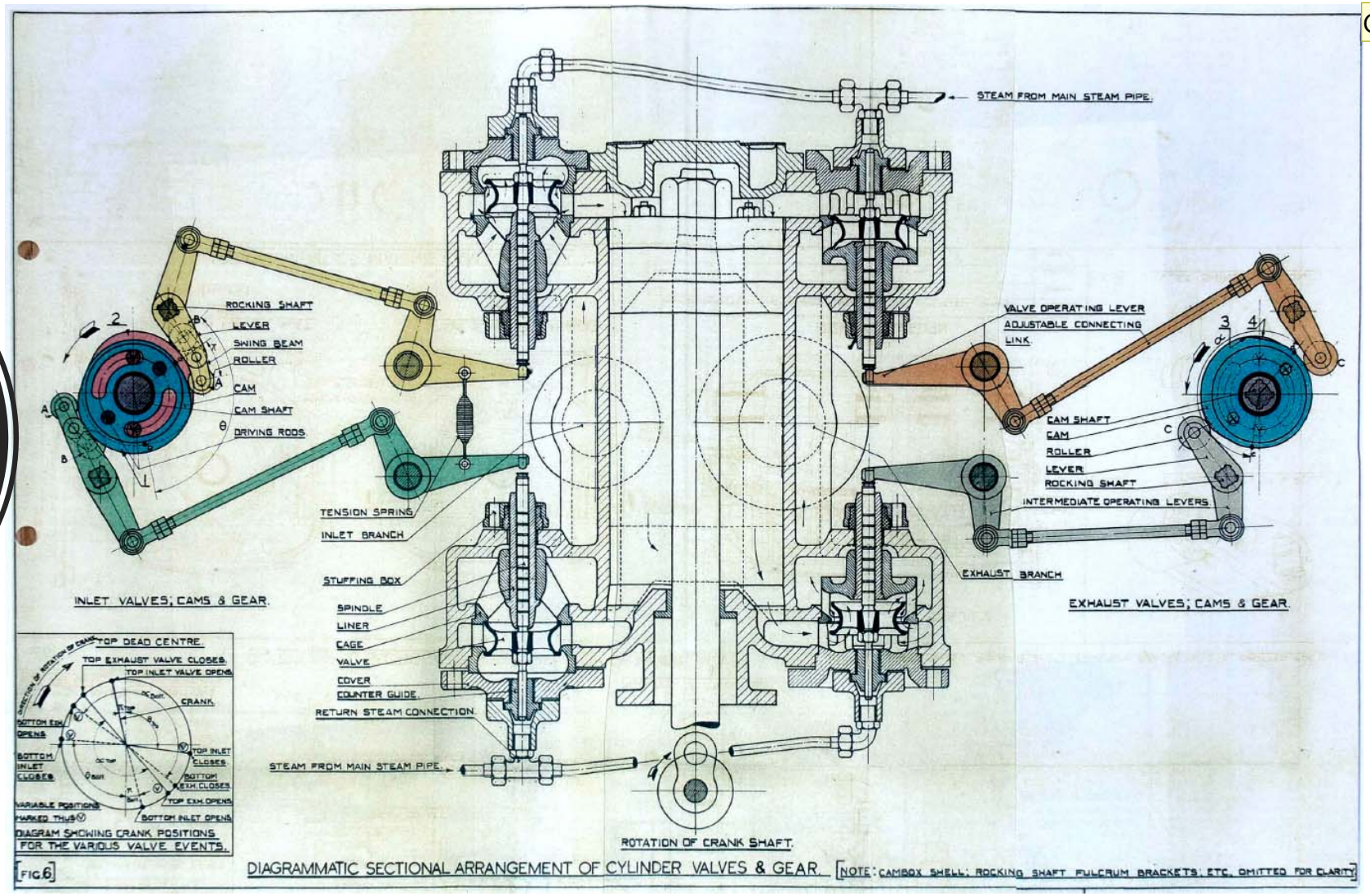
Beardmore's drawing office

Falmouth Dock Tug St Deny's Formally the Northgate Scot





Marine Caprotti

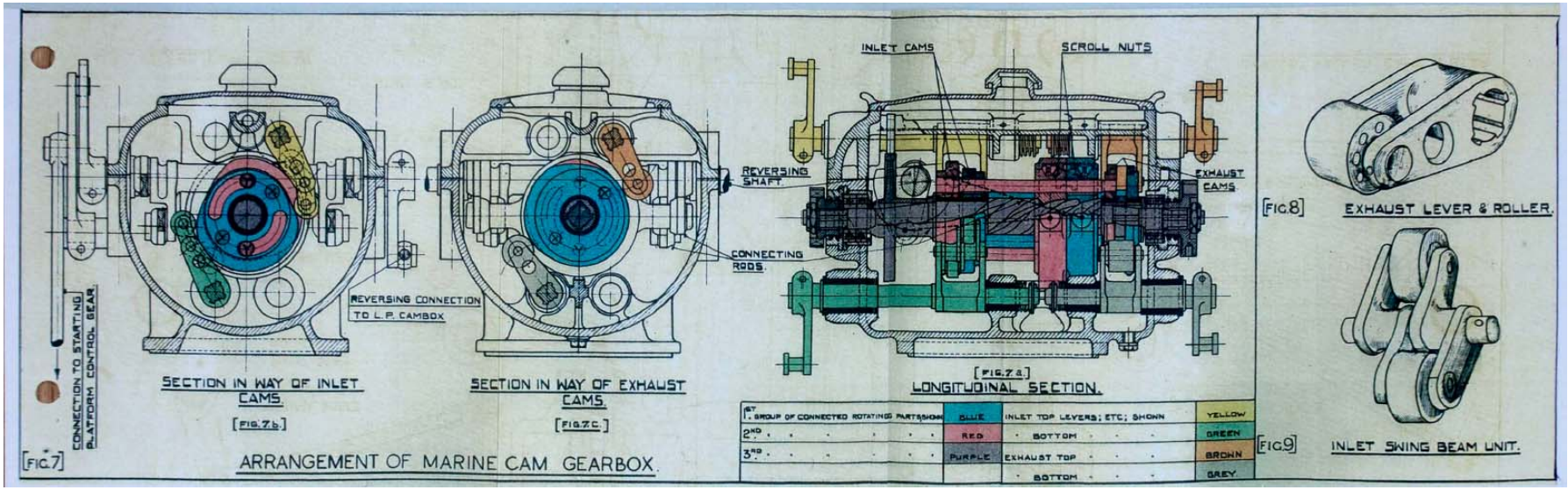


GS0 C176 Caprotti Rotary Cam Valve gear for Marine Engines Description Instruction

G Shirley, 2023-05-17T19:25:06.894

GS0

Marine Caprotti Cambox

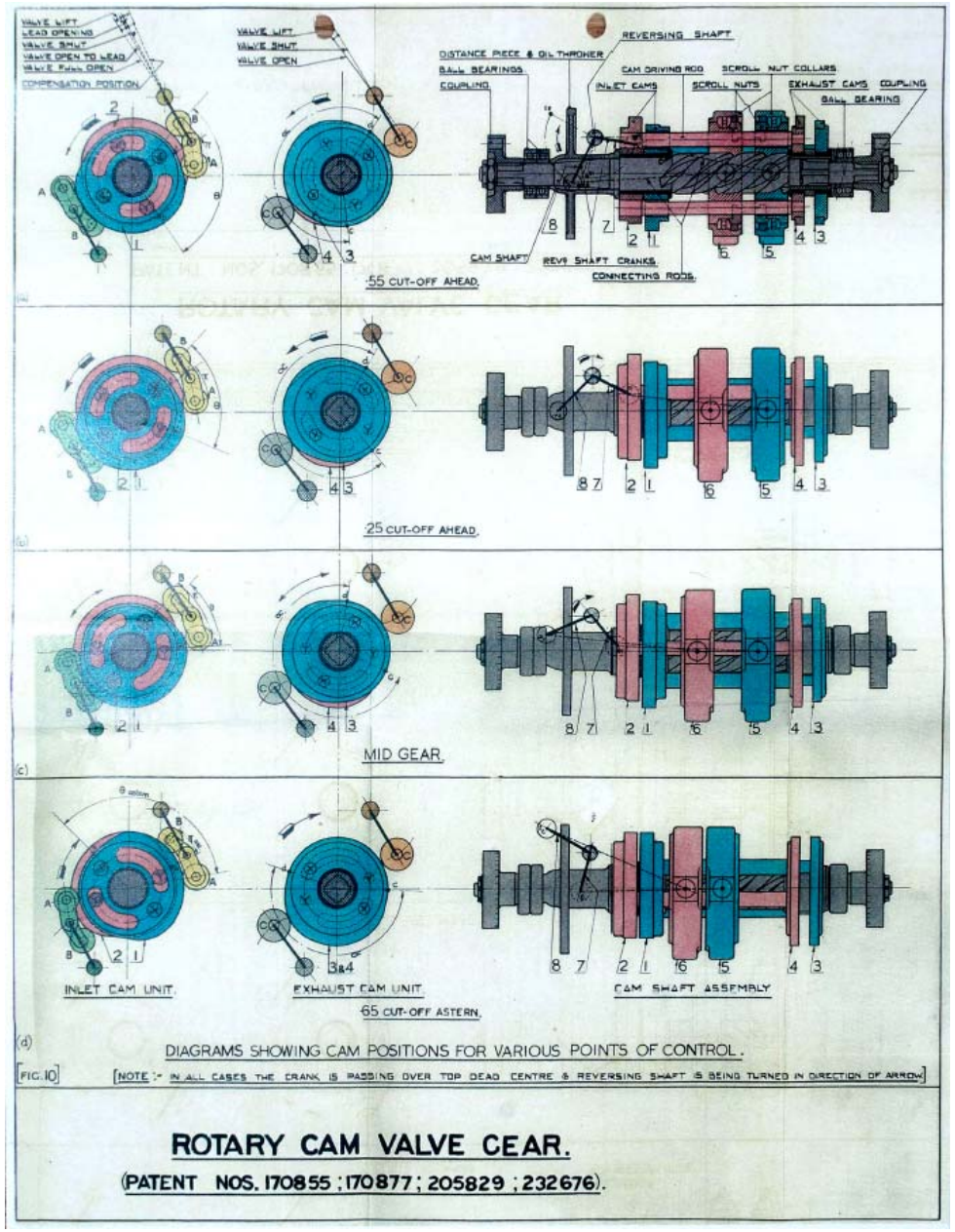


GS0 C176 Caprotti Rotary Cam Valve gear for Marine Engines Description Instruction

G Shirley, 2023-05-17T19:25:18.640

GS0

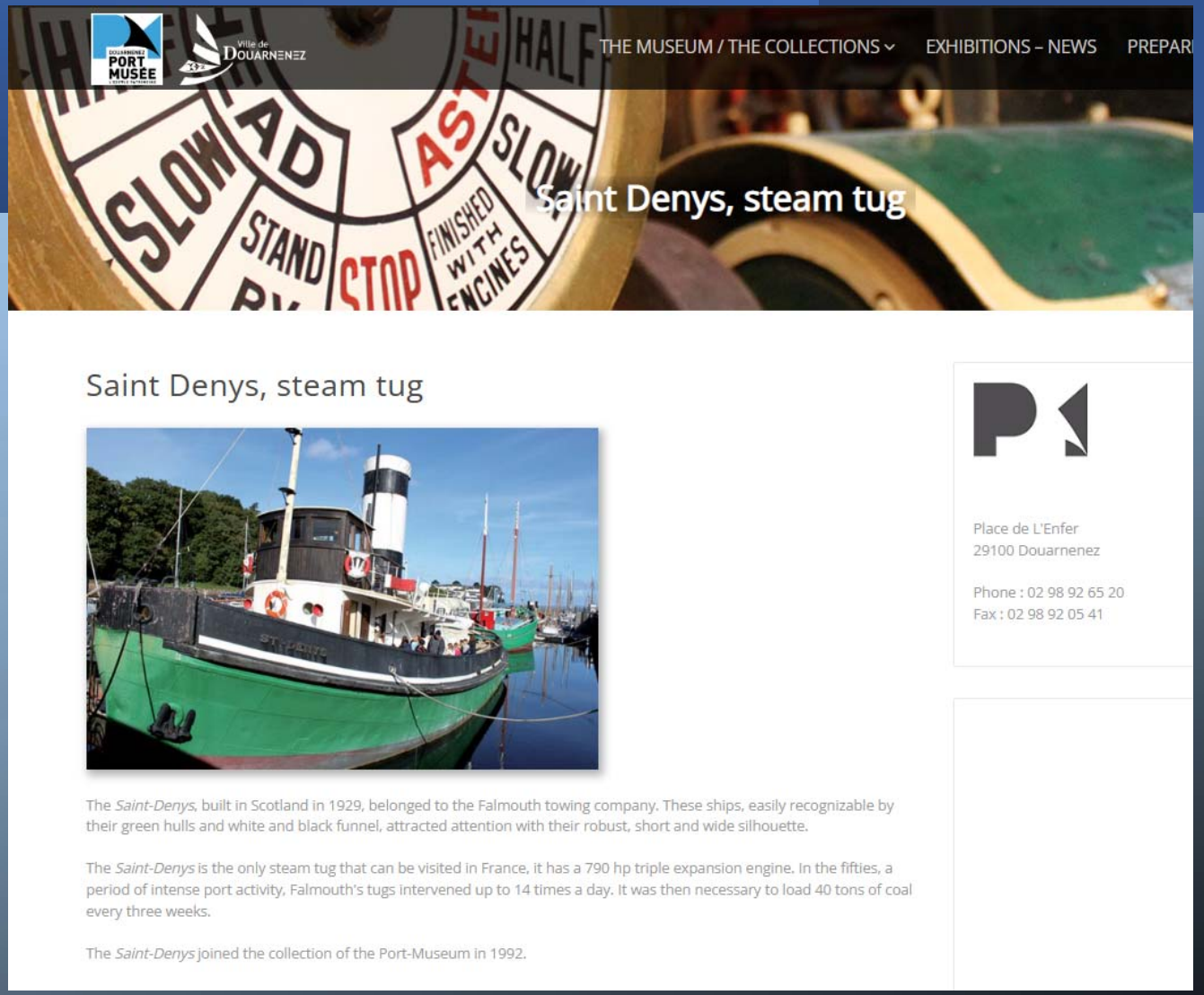
Marine Caprotti



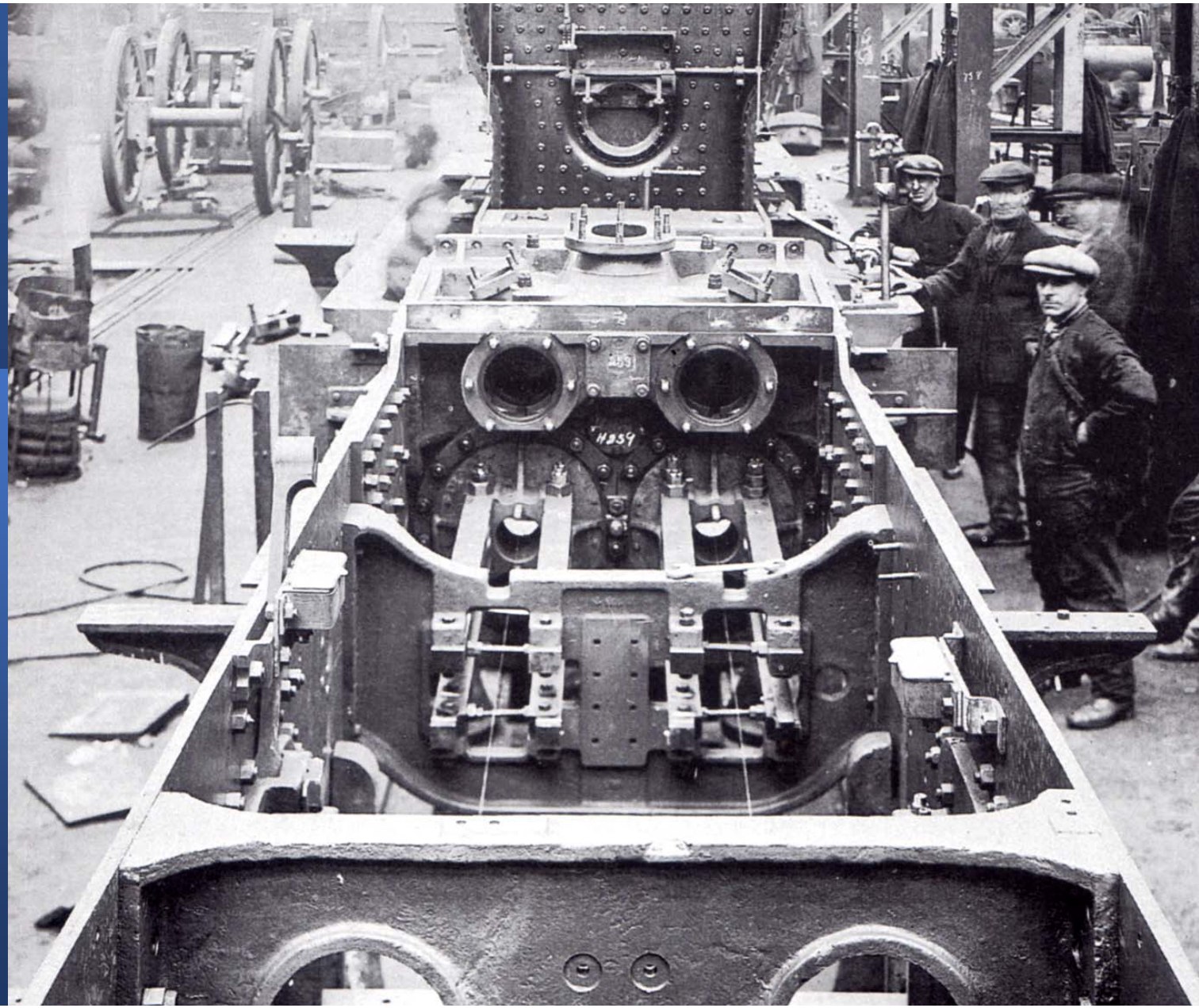
GS0 C176 Caprotti Rotary Cam Valve gear for Marine Engines Description Instruction

G Shirley, 2023-05-17T19:25:30.304

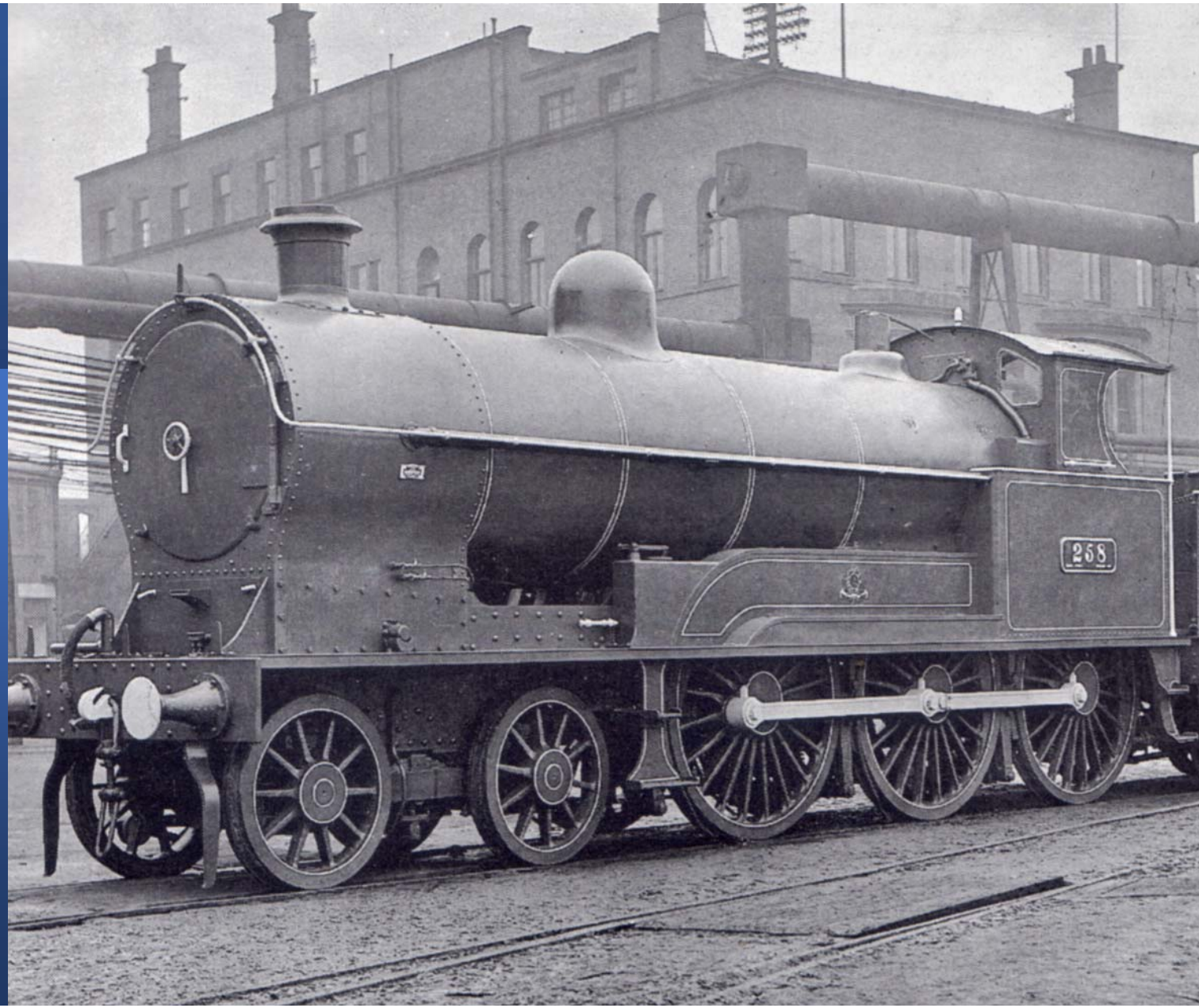
- Falmouth tug with 50 year service with Falmouth towage.
- Now in a French museum.
- The web site does not mention it’s Caprotti Heritage.
- The most efficient engine in the fleet.
- It’s near miss when bombed in the War..
- Post war upgrade.



Locomotive Building



LNWR Prince of Wales –Joy Valve gear



Caprotti's sales facts for Italian Cambox Design

Comparison with Link-Motion Gears

In the following table the Caprotti gear is compared with the three gears mostly used on express engines. Walschaerts, (Gr. 685 Italian State Railways), Stephenson's of a British made engine (Beardmore's L. 2 inside cylinders) and Joy's gear of the "Prince of Wales" at different practical cut-offs as to the expansion and compression phases: the same being figured in degrees of the crank's angular motion.

GEAR	CUT-OFF	72%	60%	50%	40%	25%	15%
Caprotti	expansion	24°	28°30′	50°	61°30′	80°	94°30′
	compression	60°	60°	60°	60°	60°	60°
Walschaerts	expansion	30°	32°	44°	51°30′	57°	52°
	compression	30°	32°	39°	43°	50°	56°
Stephenson	expansion	26°	27°	34°	37°30′	42°	44°30′
	compression	25°	26°30′	45°	36°	41°	44°
Joy	expansion	27°	30°	40°	45°	48°	50°
	compression	25°	29°	44°	36°	38°	42°

If we go over to the lesser working cut-offs, Caprotti's gear can provide for expansions as ample as 120° with 3% cut-off which cannot be obtained by any other gear, while the compression remains about the same, that is 60°. This extent of compression has been found good on the Italian State engines, but is no fixed value; it can be changed at will according to requirements.

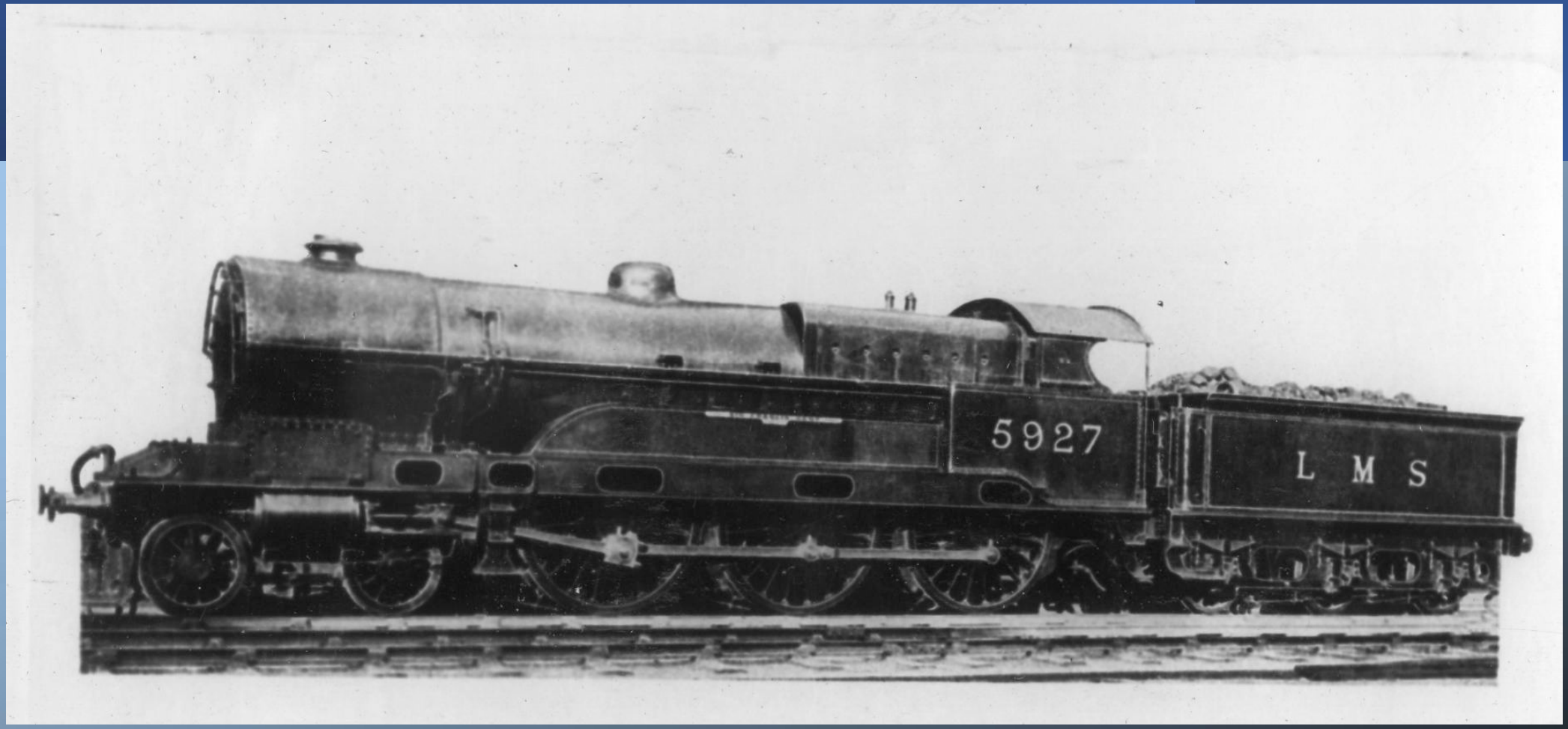
- REF: Beardmore A New Locomotive Distribution Gear using poppet valves

LNWR Claugtons

The guiding light at this time was H.P.M, Beames who was the resident engineer at Crewe, though not the Chief Mechanical Engineer of the LNWR, Beames was a Caprotti exponent and later produced schemes for the conversion and building of more ex LNWR, loco's with the gear .

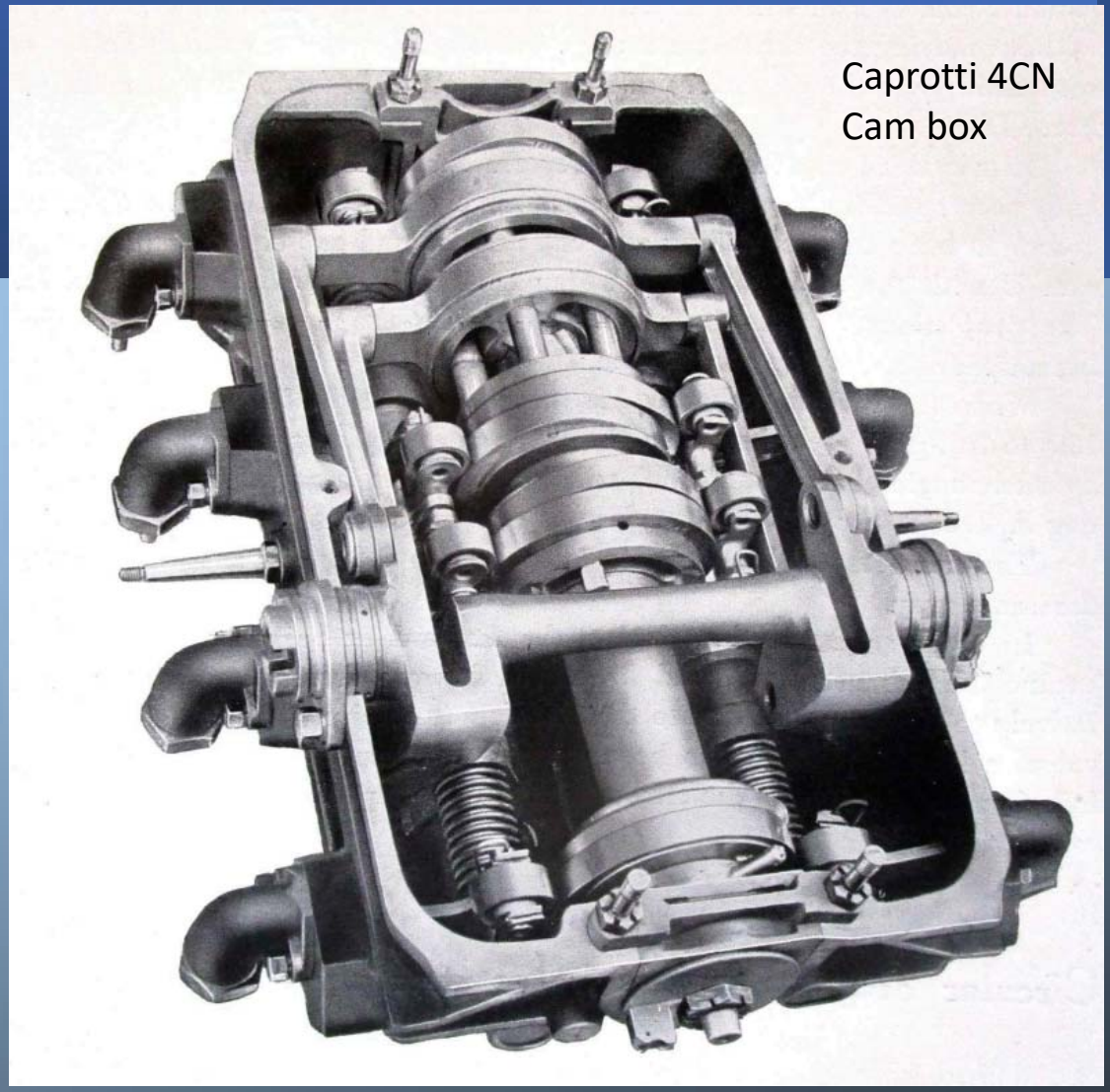
Locomotive 5908, latterly LNWR No. 1327 (Alfred Fletcher) was turned out of Crewe works in July 1926 with Italian made Caprotti 4 CN gear . In this type two camboxes drove 2 pistons each - eight valves associated with one inside cylinder, one outside the frames.

GS0



GS0 C028 Caprotti propoganda letter

G Shirley, 2023-05-10T20:22:57.426



Caprotti 4CN
Cam box

GS0

Caprotti Engine 5908

EUSTON.

M. 1-8

28th April, 1931.

MEMORANDUM TO -
S.J. SYMES, ESQ.

"CAPROTTI" ENGINE NO. 5908.

The valve gear of the above engine was examined at Crewe Works on 27/4/31 on the occasion of its receiving a service repair.

This is the original engine to be fitted with Caprotti valve gear, and has since then run 214,000 miles. Since last general repair, 42,000 miles have been run. At 30,300 miles, just before the recent Dynamometer Car tests, the valves were examined, but apart from changing one cracked valve no work was done on them.

The following notes describe the condition of the various parts :-

VALVES.

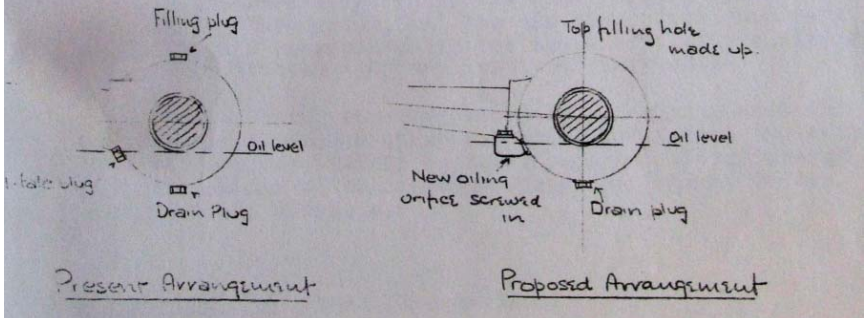
Seven of the inlet valves and five of the exhaust are the original valves fitted when the engine was converted in 1927.

The general condition of the valves was very good. The inlets had a light coating of carbon. There were no signs of cut faces or seats, or of blowing through. One valve and its seating was observed to be slightly

LUBRICATION.

Referring to the complaints of high oil consumption of the gear drive, the present oiling arrangements of the bevel box on the driving shaft are such as to allow the box to be overfilled, (see sketch). When thick oil is being poured into the top filler hole with the tell-tale open, so much will cling to the axle and gear wheels that if pouring is continued until the oil emerges from the tell-tale, the total contents of the box will be excessive.

The top plug might be replaced by a new filler hole similar to that on motor car back axles, which would make overfilling impossible as indicated in the accompanying sketch.



E.S.Cox

Slide 20

GS0 C062 LMS Caprotti engine 5908
G Shirley, 2023-05-10T20:33:40.814

GS0 0 C062 Claughtons Tests on loco fitted with Caprotti
G Shirley, 2023-05-10T20:34:17.989

GS0 1 C062 Claughton Class working Leeds to Carlisle
G Shirley, 2023-05-10T20:34:41.819

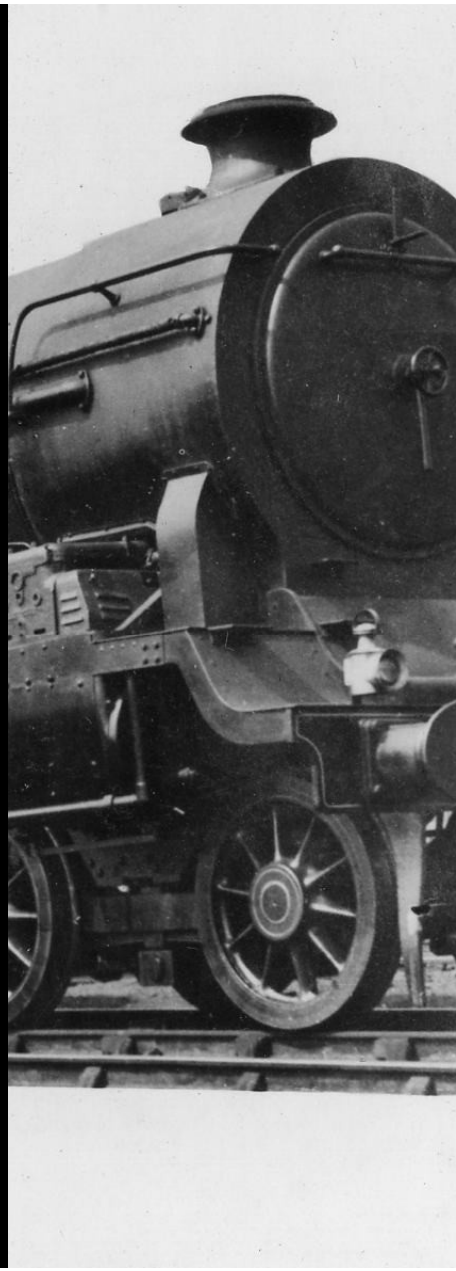
LOCO TYPE	STD CLAUGHTON	PV REBUILD	CAPROTTI	PATRIOT
Cost of shop repairs	5.04	5.37	3.09	2.95
Cost of shed repairs	2.00	2.03	2.08	1.79
Total repair cost (pence/mile)	7.04	7.40	5.17	4.74
Savings based on 40,000 miles	-	No saving	£313	£386
Actual mileage	37,219	40,729	53,677	54,629
Coal:-				
lbs/mile	55.3	50.6	50.0	47.5
pence/mile	4.74	4.33	4.30	4.07
saving based on 40,000 miles	-	£68	£75	£112
Overall saving	-	£68	£388	£498

GS0

Caprotti on the LNER B3 Lord Farringdon

- 4 cylinder 4-6-0

He was talking of troublesome engines, especially of the K3 type on the L.N.E.R. for which he has the strongest aversion. "Yes, we've had some trouble with those engines at one time or another. And then there were the Lord Farringdon's with Caprotti gear. Lord, we did have some fun with those when they first came out. They had poppet valves controlled by springs, and the heat of the steam drew the temper of the springs, and then you did'nt know where you were. Later they were changed for steam-operated valves, and then, I must say, the gear gave splendid results. Do you know that it saved 40 % of coal and water?" I expressed polite incredulity. "Yes, 40 %, I'll go on oath. Of course the original engines had a poor design of Walschaerts gear, but there's no doubt of the good results of Caprotti gear".



Slide 22

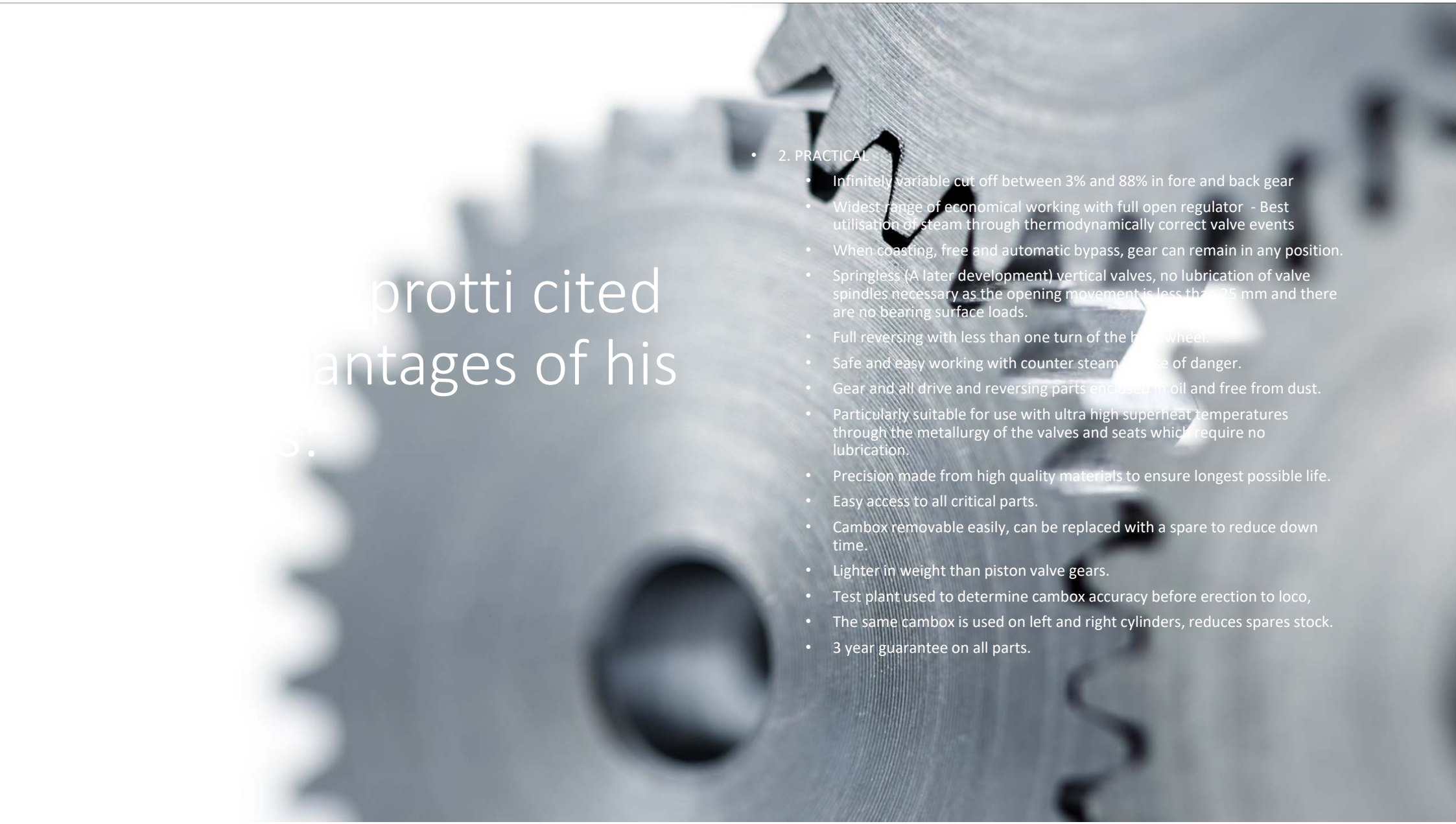
GS0 C028 Caprotti propoganda letter

G Shirley, 2023-05-10T20:35:38.791

Arturo Caprotti cited the advantages of his gear as:

Economic:

- Reduced fuel consumption
- Reduced oil consumption
- Minimum of maintenance costs
- Smallest stock of spare parts



protti cited
antages of his
s:

- 2. PRACTICAL
  - Infinitely variable cut off between 3% and 88% in fore and back gear
  - Widest range of economical working with full open regulator - Best utilisation of steam through thermodynamically correct valve events
  - When coasting, free and automatic bypass, gear can remain in any position.
  - Springless (A later development) vertical valves, no lubrication of valve spindles necessary as the opening movement is less than 25 mm and there are no bearing surface loads.
  - Full reversing with less than one turn of the hand wheel.
  - Safe and easy working with counter steam [illegible]e of danger.
  - Gear and all drive and reversing parts enclosed in oil and free from dust.
  - Particularly suitable for use with ultra high superheat temperatures through the metallurgy of the valves and seats which require no lubrication.
  - Precision made from high quality materials to ensure longest possible life.
  - Easy access to all critical parts.
  - Cambox removable easily, can be replaced with a spare to reduce down time.
  - Lighter in weight than piston valve gears.
  - Test plant used to determine cambox accuracy before erection to loco,
  - The same cambox is used on left and right cylinders, reduces spares stock.
  - 3 year guarantee on all parts.

4-6-0 TYPE, 2 CYLINDER LOCOMOTIVE FITTED WITH "R.C." TYPE POPPET VALVE GEAR. G. W. Rly.

ALE Rotary Cam Gear - Franklin

R.C. POPPET VALVE GEAR FITTED TO 4-4-0 3 CYLINDER EXPRESS PASSENGER ENGINE.

OFFICE MEMO. 30th September, 1940.

CONVERSATION BETWEEN MR. HAWKESWORTH, ASISTANT CHIEF MECHANICAL ENGINEER GREAT WESTERN RLY., AND MAJOR CANTLIE.

On a recent official visit to Swindon, I had the opportunity of a long talk with Mr. Hawkesworth on the subject of locomotive No. 2935 - Caynham Court, which is fitted with the A.L.E. Gear.

Mr. Hawkesworth stated that when this engine was first fitted numerous tests were carried out by the Railway in conjunction with the A.L.E. Company and that the latter had been granted full facilities to obtain the best possible results. Despite this however, the locomotive had always been notably heavier in water consumption than other engines of the same class, and had also exhibited less hauling power. The engine had been in service on the Weymouth Branch which had heavy grades, and comparison had been made with similar locomotives of the same class.

Mr. Hawkesworth stated that he had talked with L.N.E.Rly. Officials who had a number of A.L.E. geared locomotives in their service, and they stated that his experience of heavier water consumption tallied with theirs. I have since talked to an L.N.E.Rly. Official who denies that these engines are heavy, and on the contrary states that they are lighter in coal and water consumption than the Piston Valve Engines.

Mr. Hawkesworth stated that he had no prejudice against the A.L.E. Gear and poppet valves, in fact he liked the beat of engine No. 2935 and was only sorry that better results were not being obtained, as in his opinion Poppet Valves would certainly come sooner or later. He stated however, that in his opinion engine No. 2935 would be fitted with Piston Valves when the present Cylinders were worn out, as the Railway felt that they had made all possible experiments and that during the War period they could do no more.

I informed him that I had heard that the results obtained on this engine were not good and that

The Take over

Hugo Lentz
(Own company Austria)

1923 W. Dederich & Co
Agents for German manufactures

1924 Lentz Patents Ltd
London – Manufacturing agents

1925 Kyle chap Exhausts + Dabeg feed pump

1934 Dabeg Slack Adjuster

1931 Associated Locomotive Equipment Ltd
London – Manufacturers of Oscillating Cam and Rotary cam valve gear based on Lentz. 54 Victoria St, London

Arthuro Caprotti
(Own company Italy)

1923 Valve Gears Ltd
Glasgow – manufactures sponsored by W. Beardmore

1932 Caprotti Valve Gears Ltd.
66 Victoria St ,London – Design & manufactures


BEARDMORE
-CAPROTTI
LOCOMOTIVE
Valve Gear
Using Poppet Valves
(A. Caprotti's Patents)
To railway engineers and all who are interested in the construction, operation and maintenance of Steam Locomotives.
WILLIAM BEARDMORE
Sole Manufacturers for the United Kingdom
PARKHEAD :: GLASGOW
and
Locomotive Works
DALMUIR
Dumbartonshire

Hauber Piston Packing

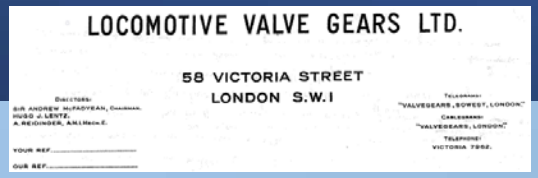
1935 Heinl Feed pump

1936 Motorvapore Steam Motors (Milan) Marine Caprotti

1936 Caprotti valve gear Ltd brought out ALE

1937 Franklin NY

CVG active


LOCOMOTIVE VALVE GEARS LTD.

58 VICTORIA STREET
LONDON S.W.1

1939 Kylchap Exhaust

ALE Dormant

A Reidinger left to work with Rendel Parmer and Tritton

1944 CVG as a company discontinues

ALE Resurrected to contain all activities of CVG and dormant ALE, 32 Duke St, London

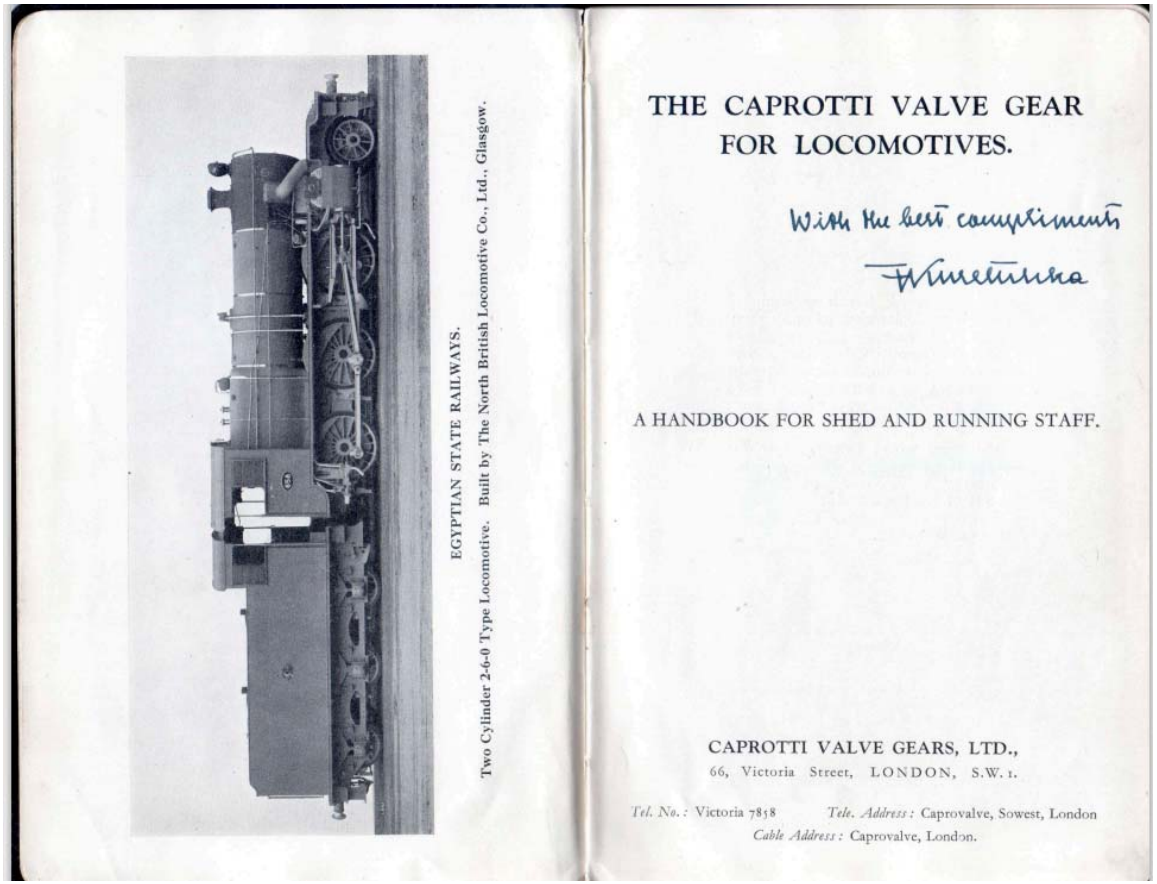
Reidinger forms own company

Locomotive Valve gears Ltd, 30/34 Buckingham Gate, London

1969 Dissolved

1966 Cease of Trading

F J Kruretschka takes Charge charge…
Ex WW1 U-Boat Captain.
Naval organization in the office
Effective Technical control.
Respected in the industry.
But not for long



EGYPTIAN STATE RAILWAYS.
Two Cylinder 2-6-0 Type Locomotive. Built by The North British Locomotive Co., Ltd., Glasgow.

THE CAPROTTI VALVE GEAR FOR LOCOMOTIVES.

With the best compliments
F Kruretschka

A HANDBOOK FOR SHED AND RUNNING STAFF.

CAPROTTI VALVE GEARS, LTD.,
66, Victoria Street, LONDON, S.W. 1.

Tel. No.: Victoria 7858 *Tele. Address:* Caprovalve, Sowest, London
Cable Address: Caprovalve, London.

Kruretschka –
Leaves for holiday.
He did not expect
War to start in
September
He never returned

INSTRUCTIONS FJK/MJ.

GENERAL OFFICE
DRAWING OFFICE. 14th August, 1939.

Mr. Cantlie .....
Miss Farrant .....
Mr. Lunt .....

During my absence the office is to carry on as before when I have been away. Reports to be posted every day in the usual manner.

E.S.R. QUOTATIONS FOR 4 CYLINDERS FOR 600 CLASS ENGINES.
As a result of my last visit to the E...R. they have now enquired from us for the first time for replacement cylinders. The quotation has been submitted and is now under consideration to be placed ...r offer was

...ithout study, ...ese be ...uotations from Beyer Peacock for the additional work. In any case get into touch with Mr. Ablett.

L.N.E.R. If Johnson can obtain an Engine Pass from Mr. Dawson, he shall visit Woodford again a fortnight after the conclusion of his present visit.

War begins

EMERGENCY. 23/8/3.

The International situation is now so tense that it is necessary to prepare for any eventuality as quickly as possible.

While war is not regarded as inevitable, it is much better to prepare for all possible eventualities as we then have a concrete plan to guide us, whatever the situation may be.

The various possibilities seem to be :-

1. Mobilisation not followed by war;
2. Mobilisation followed by war;
3. A sudden act of war before mobilisation is either commenced or completed;
4. Indefinite extension of the present situation.

22nd November, 1940.

Dear Morton

I passed 66 Victoria Street this morning, and noted that four windows were broken and one was cracked. I therefore went into the office, and though the liftman could not discover a key, I was fortunate in being able to enter through the former offices, in order to check the windows. While there, I noted that the cam box was standing by one of the broken windows and that a good deal of the steel was slightly rusty. I therefore moved the cam box away from the window, and that is all that can be done for the moment.

It is recommended that from the period of declaration of a state of emergency by the Government, the staff should carry to and from their homes :

a) Gas mask;
b) Mackintosh (Rubberised)
c) Sou'wester
d) Leather gloves.
e) Rubber overshoes.

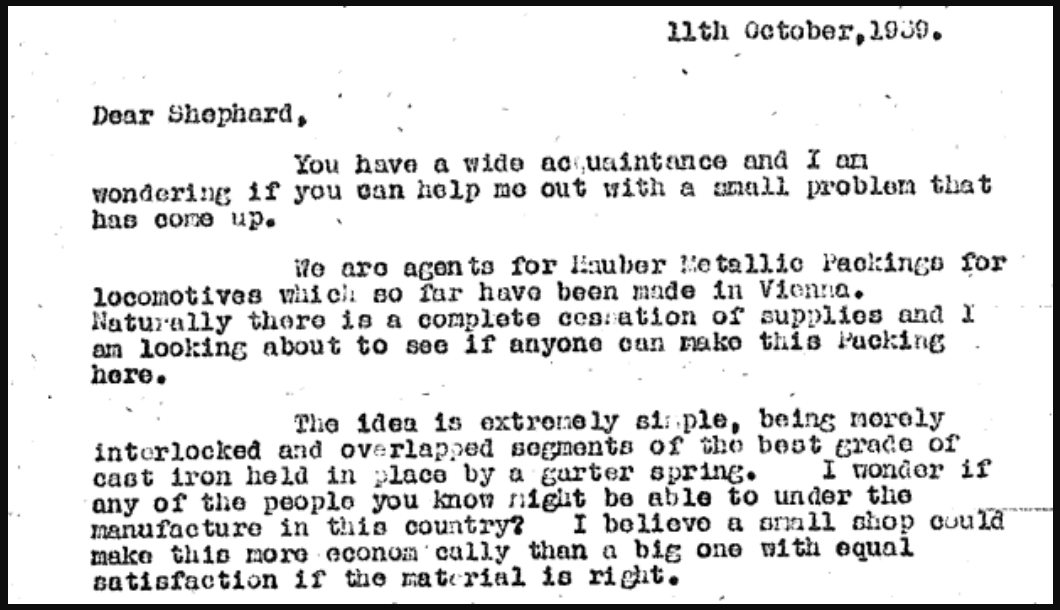
There seems to have been quite a lot of trouble in the Westminster District since we left, as for instance the North British Locomotive Co. Ltd. found their Victoria Street offices completely destroyed and one or two other places have been badly damaged, so that perhaps after all we were well advised to come down here even if our relative immunity is only for the time being.

Yours sincerely,

E Morton.

Major Cantlie addresses War time shortages

- German sourced parts
- Italian sourced parts.
- Hauber Piston Packings
- Heinl Feed pumps
- Dabeg Slack adjuster
- Dabeg Kylechap support
- Dabeg feed pumps.



11th October,1939.

Dear Shephard,

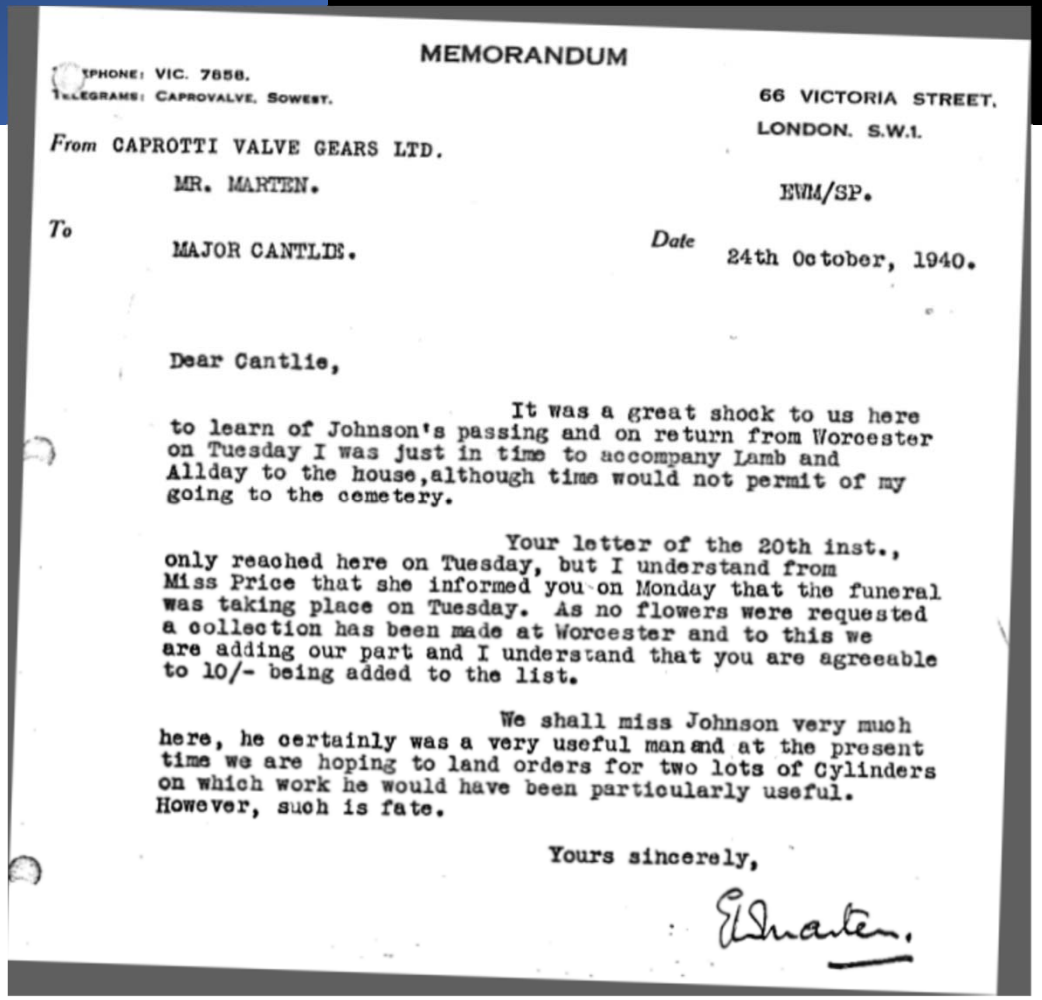
You have a wide acquaintance and I am wondering if you can help me out with a small problem that has come up.

We are agents for Hauber Metallic Packings for locomotives which so far have been made in Vienna. Naturally there is a complete cessation of supplies and I am looking about to see if anyone can make this Packing here.

The idea is extremely simple, being merely interlocked and overlapped segments of the best grade of cast iron held in place by a garter spring. I wonder if any of the people you know might be able to under the manufacture in this country? I believe a small shop could make this more economically than a big one with equal satisfaction if the material is right.

Staff loss - Johnson

Ralph Johnson died [censored] in his 35th year from injuries sustained while endeavouring to extinguish an incendiary bomb. He was educated at Stoke-on-Trent, where he gained the National Certificate while studying in the Evening Classes at the Technical College. His full mechanical training was received at Kerr, Stuart and Co., Ltd., Stoke-on-Trent, where he became a locomotive draughtsman. He later had experience in the drawing offices of the North British Locomotive Co., Ltd., Glasgow, and the Vulcan Foundry Co., Ltd., Newton-le-Willows. In 1935 he joined the Caprotti Valve Gear Co. as locomotive engineer, which position he held until his untimely decease. Mr. Johnson was a conscientious and untiring worker and will be much missed by a large circle of friends. He was recommended for election as an Associate Member of the Institution in April last.



MEMORANDUM

PHONE: VIC. 7858.
TELEGRAMS: CAPROVALVE, SOWEST.

66 VICTORIA STREET,
LONDON. S.W.1.

From CAPROTTI VALVE GEARS LTD.
MR. MARTEN.

EWM/SP.

To MAJOR CANTLIE.

Date 24th October, 1940.

Dear Cantlie,

It was a great shock to us here to learn of Johnson's passing and on return from Worcester on Tuesday I was just in time to accompany Lamb and Allday to the house, although time would not permit of my going to the cemetery.

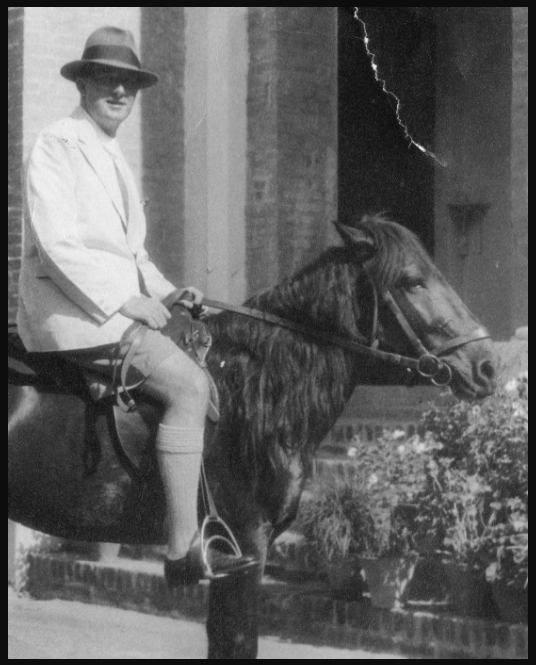
Your letter of the 20th inst., only reached here on Tuesday, but I understand from Miss Price that she informed you on Monday that the funeral was taking place on Tuesday. As no flowers were requested a collection has been made at Worcester and to this we are adding our part and I understand that you are agreeable to 10/- being added to the list.

We shall miss Johnson very much here, he certainly was a very useful man and at the present time we are hoping to land orders for two lots of Cylinders on which work he would have been particularly useful. However, such is fate.

Yours sincerely,

E Marten.

Mr E W Martin takes over from Major Cantlie



24th July, 1940.

W.A. Stanier, Esq.,
Chief Mechanical Engineer,
London Midland & Scottish Railway,
EUSTON STATION. N.

Dear Mr. Stanier,

For the last year I have, as you know, been Managing Director of Caprotti Valve Gears Ltd., and Associated Locomotive Equipment Ltd. As you are aware I entered the War Office just before the War began and since then have been able to devote certain odd periods of the day to the business of these two Companies.

Contrary to expectation, the business of these two Companies has not only been well maintained throughout the hostilities but has even increased in some respects, and this, coupled with the very long hours necessary at the War Office made a change very desirable.

These two Companies have been very fortunate in securing the services of Mr. H.W.Harten late of Beyer Peacock & Co., and Sulzer Bros Ltd., as Managing Director in my place, and I am sure that the Managing Directorship of the Companies could not have been [illegible]. I myself am remaining on the Boards and trust that our personal and [illegible] continue as cordially as before.

Yours sincerely,

(K.Cantlie)

LONDON MIDLAND AND SCOTTISH RAILWAY COMPANY

CHIEF MECHANICAL & ELEC. ENGINEERS' DEPT.

Telephone: WATFORD 6051-6056

L M S HEADQUARTERS,
WATFORD, HERTS.

In your reply please quote this reference
YOUR REFERENCE

5th August, 1940. KC/SP.

Dear Major Cantlie,

I have this morning received your letter of the 24th July, and am pleased to hear of the success of Caprotti Valve Gears Ltd., and I also note the change in the Managing Directorship.

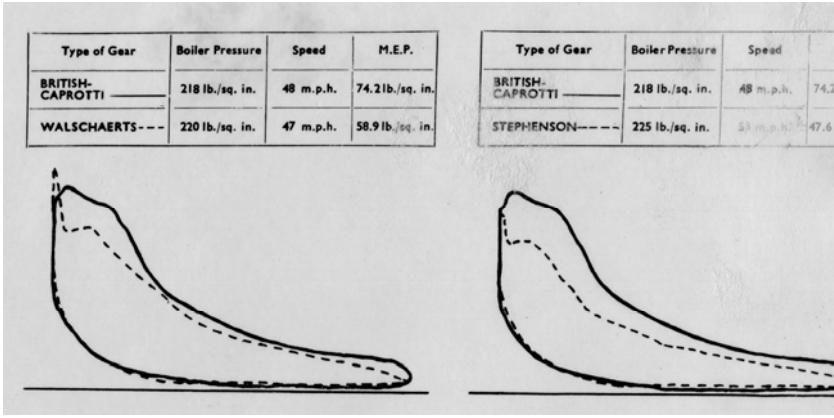
Yours faithfully,

W. A. STANIER

Major K. Cantlie,
Caprotti Valve Gears Ltd.,
66, Victoria Street,
LONDON. S.W. 1.

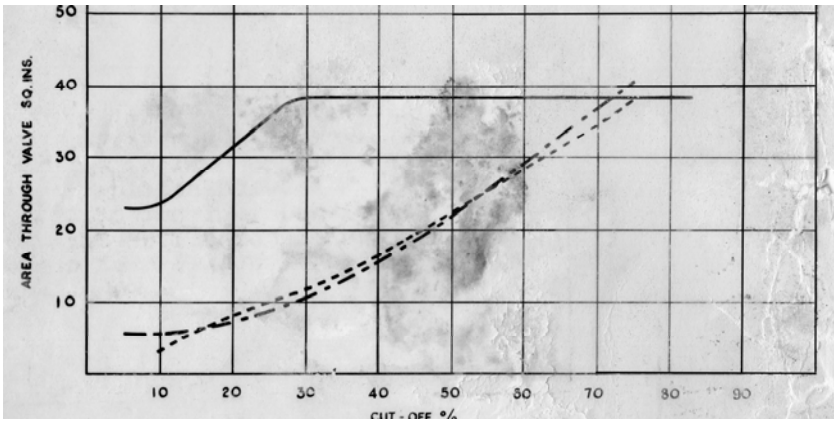
War ends

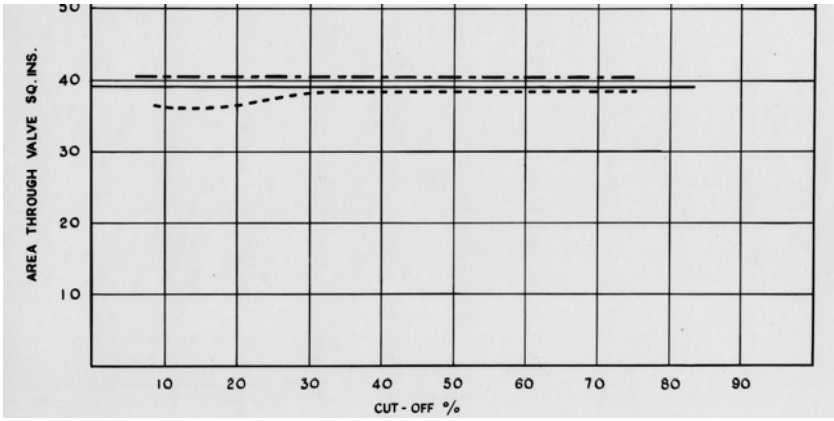
- Short comings of the original Caprotti cambox are addressed with a redesign by Fred Jones and Tom Daniels.
- Caprotti engines are free steaming, and faster only at shorter cut offs. They are suited to high-speed running. For longer cut-offs Walschaerts, Stephenson and Joy give better performance.
- Variable compression addresses poor starting acceleration of Caprotti engines, and performance at longer cut offs.



Type of Gear	Boiler Pressure	Speed	M.E.P.
BRITISH-CAPROTTI ———	218 lb./sq. in.	48 m.p.h.	74.2 lb./sq. in.
WALSCHAERTS - - -	220 lb./sq. in.	47 m.p.h.	58.9 lb./sq. in.

Type of Gear	Boiler Pressure	Speed
BRITISH-CAPROTTI ———	218 lb./sq. in.	48 m.p.h.
STEPHENSON - - - -	225 lb./sq. in.	

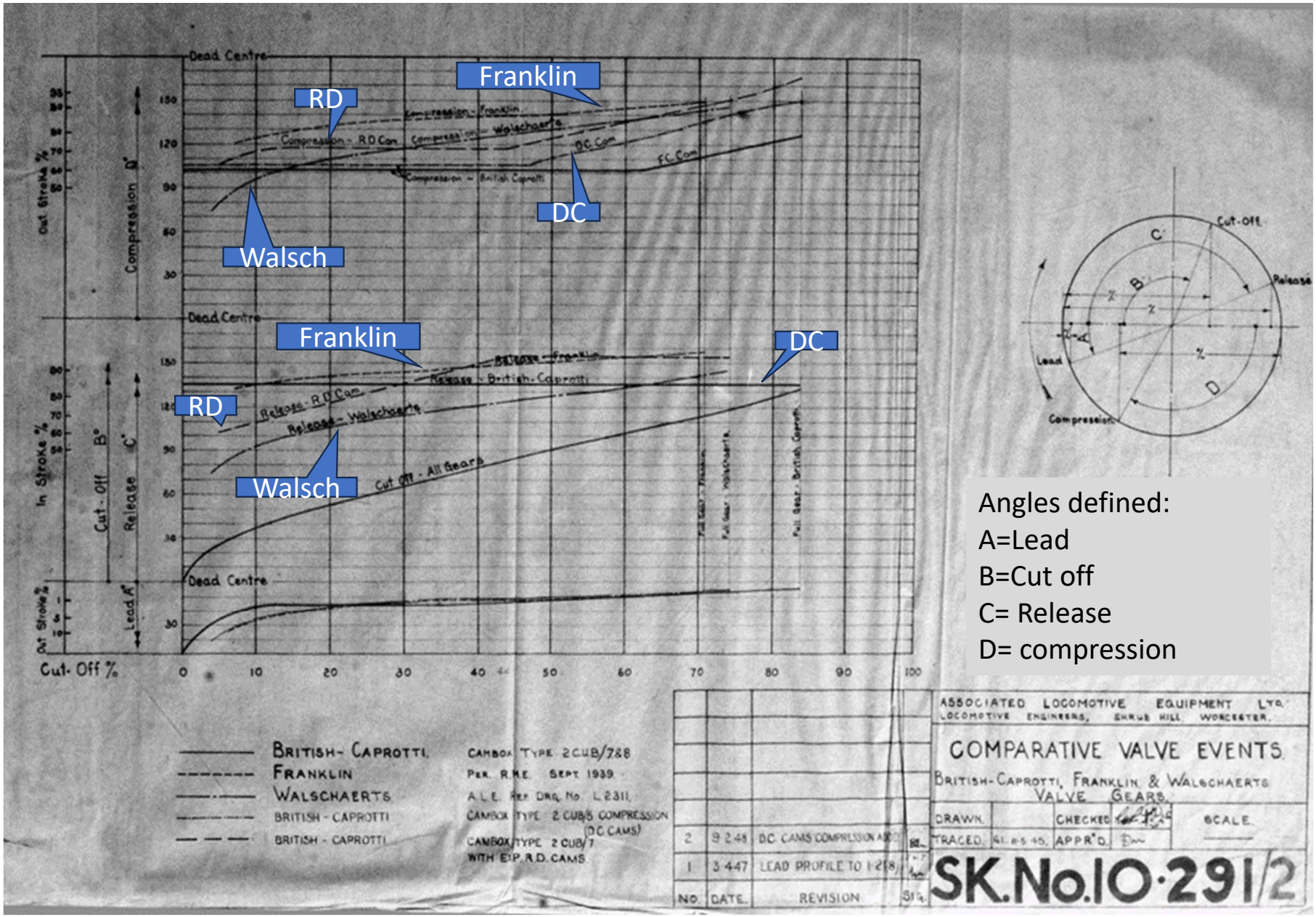


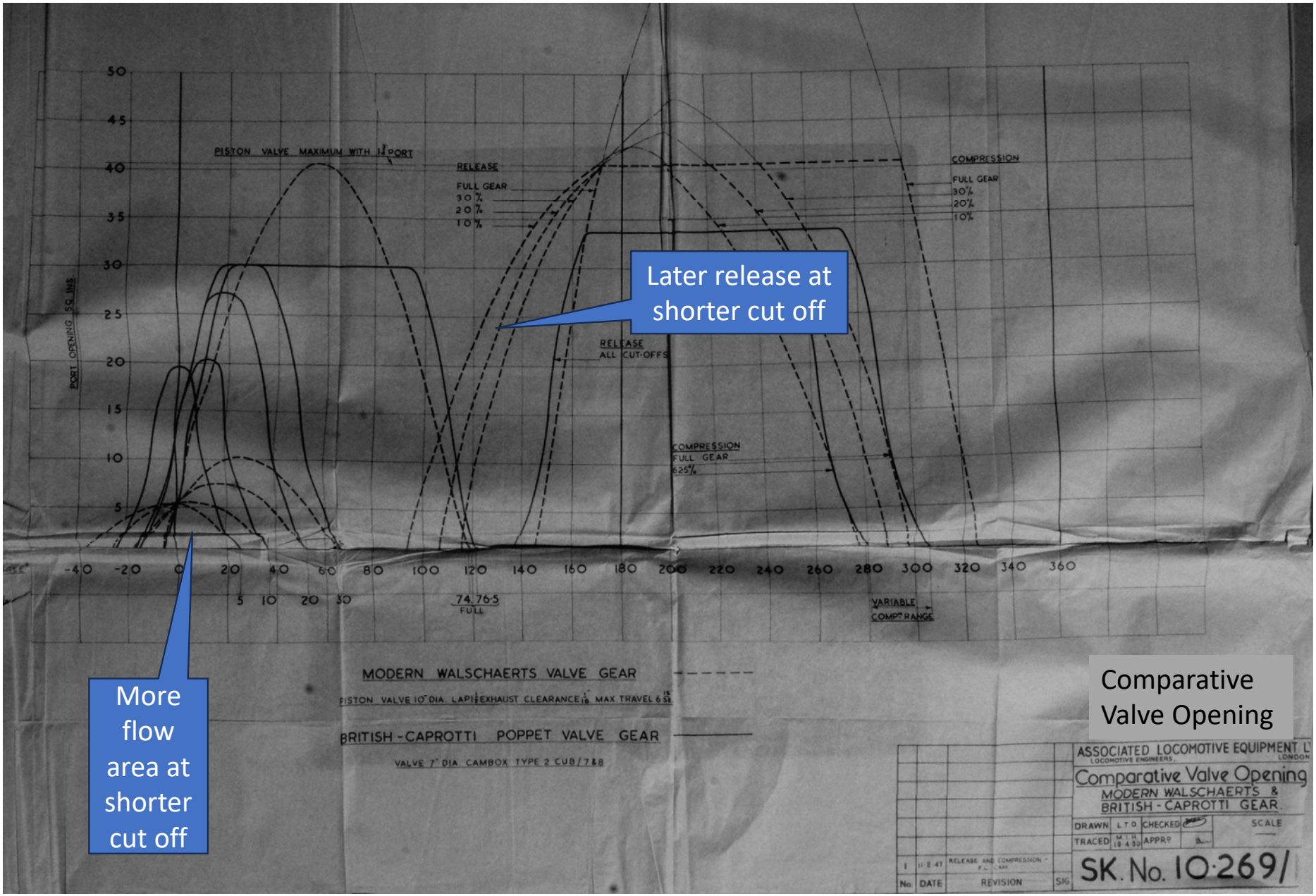


Valve gear

- 1 . Ref: C158 Cours de Locomotive A vapeur – Chapter IV- Mecanisme Tome III.
- 2. Lead is the amount by which the piston valve is open to live steam when the piston is on forward or back dead centre.
- 3. Variability of the consistency of Lead is a feature of Link geometry

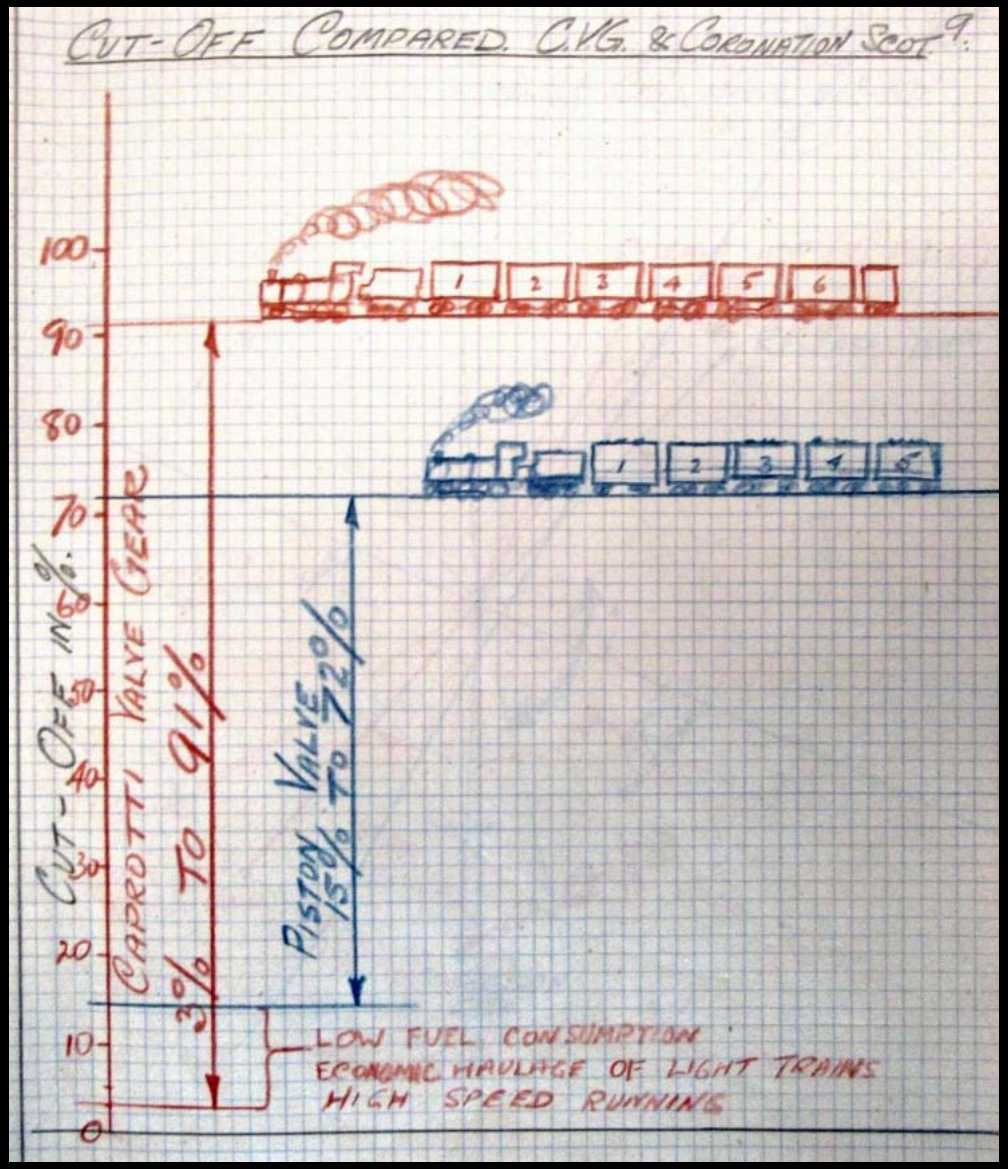
Valve gear	Lead, and valve events.
Walschaerts	Constant lead at all speed and cut offs. (1)
Stephenson	Variable lead at its maximum at full gear, decreasing to zero or negative at mid gear. (1)
Oscillatory Cam - Lentz	OC poppet valves are actuated by one link motion drive, and hence admission and exhaust events are tied.
Rotary Cam ALE RC, Caprotti, Cossart	Blank sheet of paper ! – Separation of admission and exhaust valve events is possible.


Franklin
RD
DC
Walsch
Franklin
DC
RD
Walsch
Dead Centre
Dead Centre
Dead Centre
Compression - Franklin
Compression - RD Con
Compression - Walschaerts
DC Con
FC Con
Compression - British Caprotti
Release - Franklin
Release - British-Caprotti
Release - RD Con
Release - Walschaerts
Cut Off - All Gears
Out Stroke %
In Stroke %
Compression D°
Cut-Off B°
Release C°
Lead A°
Cut-Off %
0 10 20 30 40 50 60 70 80 90 100
Cut-off
Release
Lead
Compression
A
B
C
D
Angles defined:
A=Lead
B=Cut off
C= Release
D= compression
BRITISH-CAPROTTI
FRANKLIN
WALSCHAERTS
BRITISH - CAPROTTI
BRITISH - CAPROTTI
CAMBOX TYPE 2 CUB/7&8
PER R.M.E. SEPT 1939
A.L.E. REF DRG. No. L.2311
CAMBOX TYPE 2 CUB/5 COMPRESSION (DC CAMS)
CAMBOX TYPE 2 CUB/7 WITH EXP. R.D. CAMS
2 9.2.48 DC CAMS COMPRESSION ADJ
1 3.4.47 LEAD PROFILE TO 1-218
NO. DATE. REVISION
ASSOCIATED LOCOMOTIVE EQUIPMENT LTD.
LOCOMOTIVE ENGINEERS, SHRUB HILL, WORCESTER.
COMPARATIVE VALVE EVENTS
BRITISH-CAPROTTI, FRANKLIN & WALSCHAERTS VALVE GEARS
DRAWN
CHECKED
TRACED
APPR'D
SCALE
SK.No.10·291/2


PISTON VALVE MAXIMUM WITH 1¼ PORT
RELEASE
FULL GEAR
30%
20%
10%
COMPRESSION
FULL GEAR
30%
20%
10%
PORT OPENING SQ. INS.
50
45
40
35
30
25
20
15
10
5
Later release at shorter cut off
RELEASE
ALL CUT-OFFS
COMPRESSION
FULL GEAR
62½%
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
5 10 20 30
74.76·5
FULL
VARIABLE
COMPN RANGE
More flow area at shorter cut off
MODERN WALSCHAERTS VALVE GEAR
PISTON VALVE 10" DIA. LAP 1" EXHAUST CLEARANCE 1/16" MAX TRAVEL 6 5/8"
BRITISH-CAPROTTI POPPET VALVE GEAR
VALVE 7" DIA CAMBOX TYPE 2 CUB/7&8
Comparative Valve Opening
ASSOCIATED LOCOMOTIVE EQUIPMENT LTD
LOCOMOTIVE ENGINEERS, LONDON
Comparative Valve Opening
MODERN WALSCHAERTS & BRITISH-CAPROTTI GEAR.
DRAWN L.T.D. CHECKED
TRACED 18.4.50 APPR'D
SCALE
No. DATE REVISION SIG
1 11.2.47 RELEASE AND COMPRESSION - P.V. CAM
SK. No. 10·269/

GS0

Caprotti Valve gear Challenge on the LMS Coronation Scot

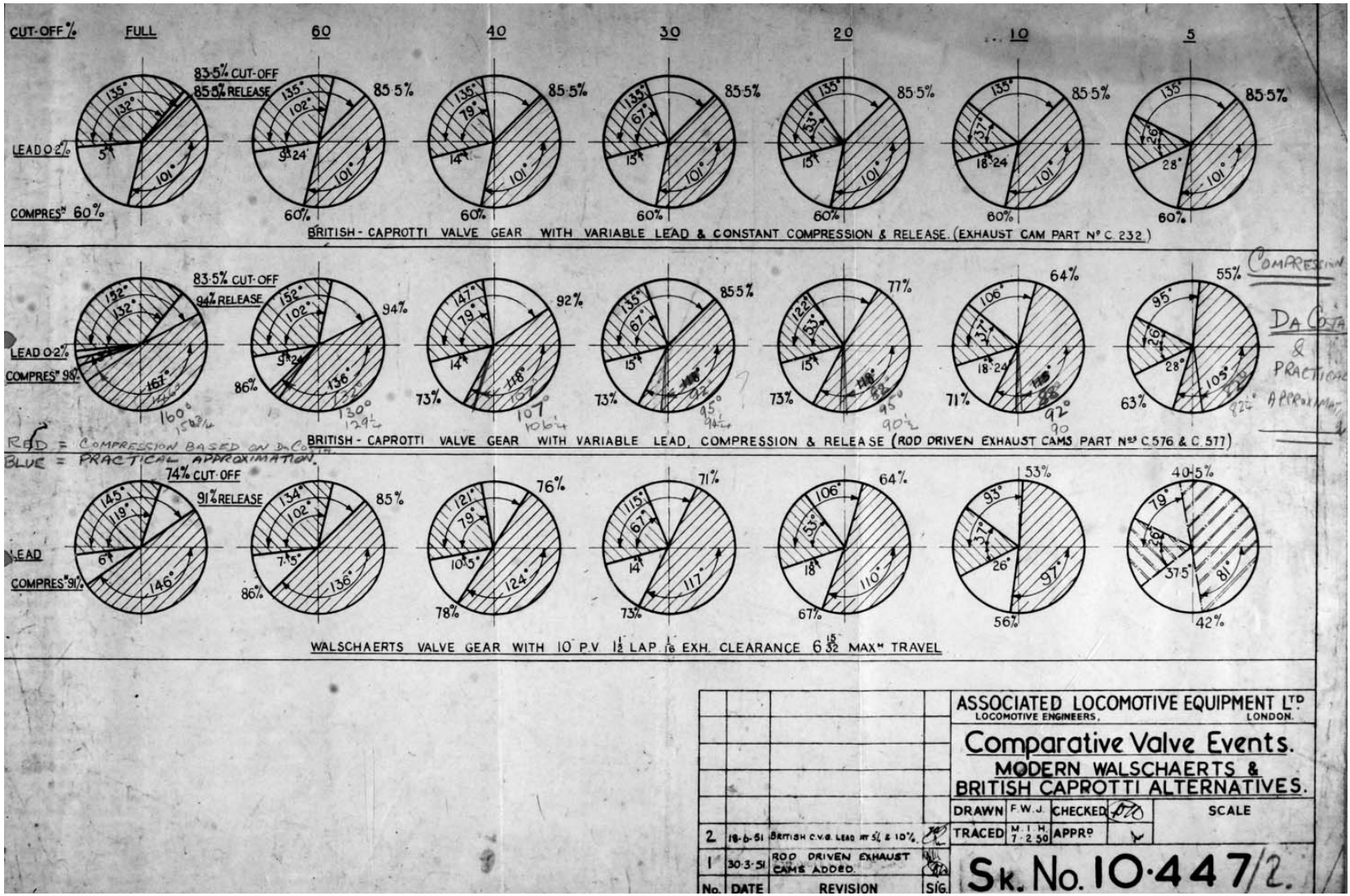


GS0 ALE VALVE AND TAPPET CAM CALC BOOK

G Shirley, 2023-05-10T20:46:25.519

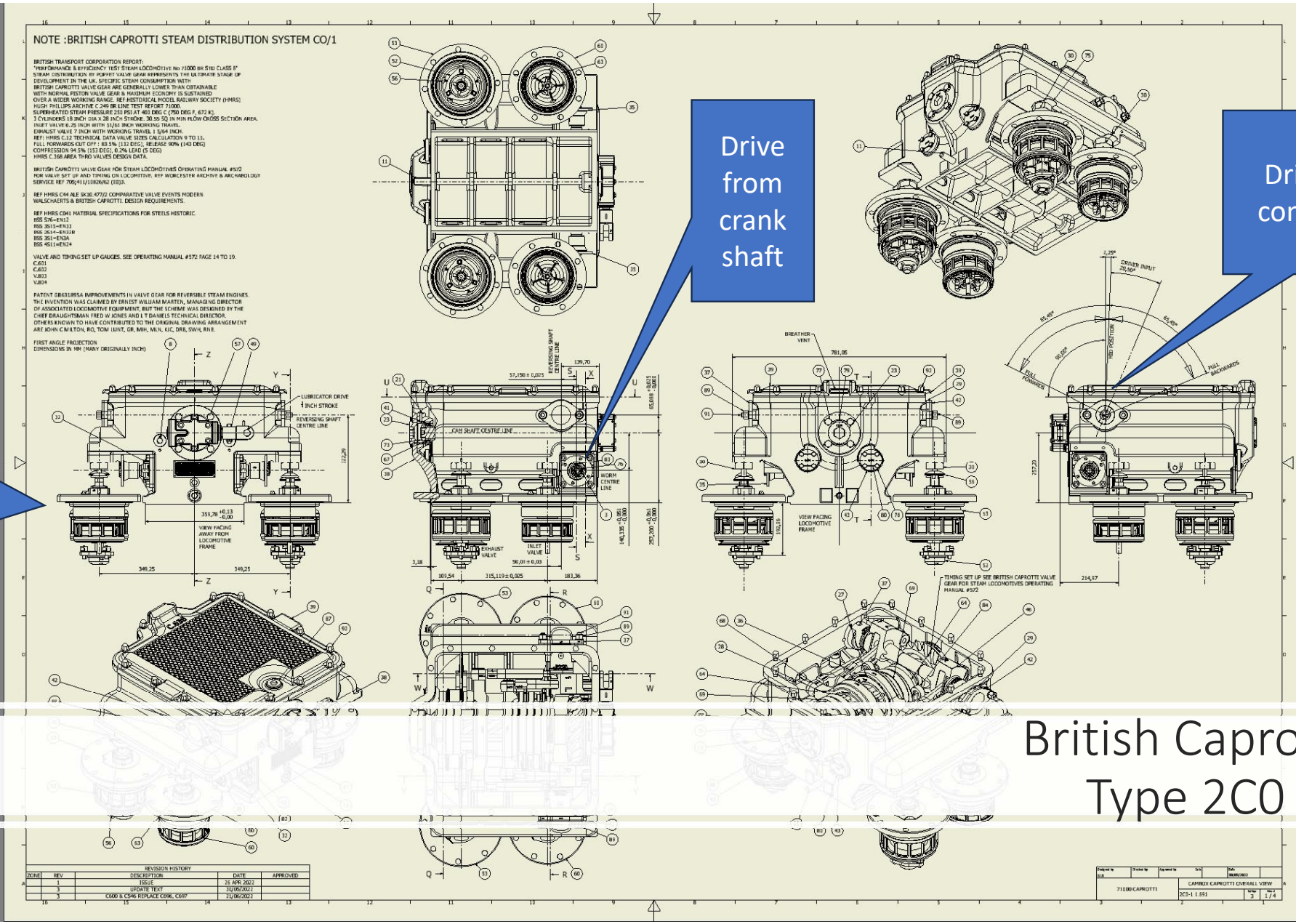
GS0

The selection on the blank sheet
Top line original Caprotti with 60% fixed compression.
Middle line, New British Caprotti with variable compression similar to Walschaerts
Bottom line Walschaert's valve events



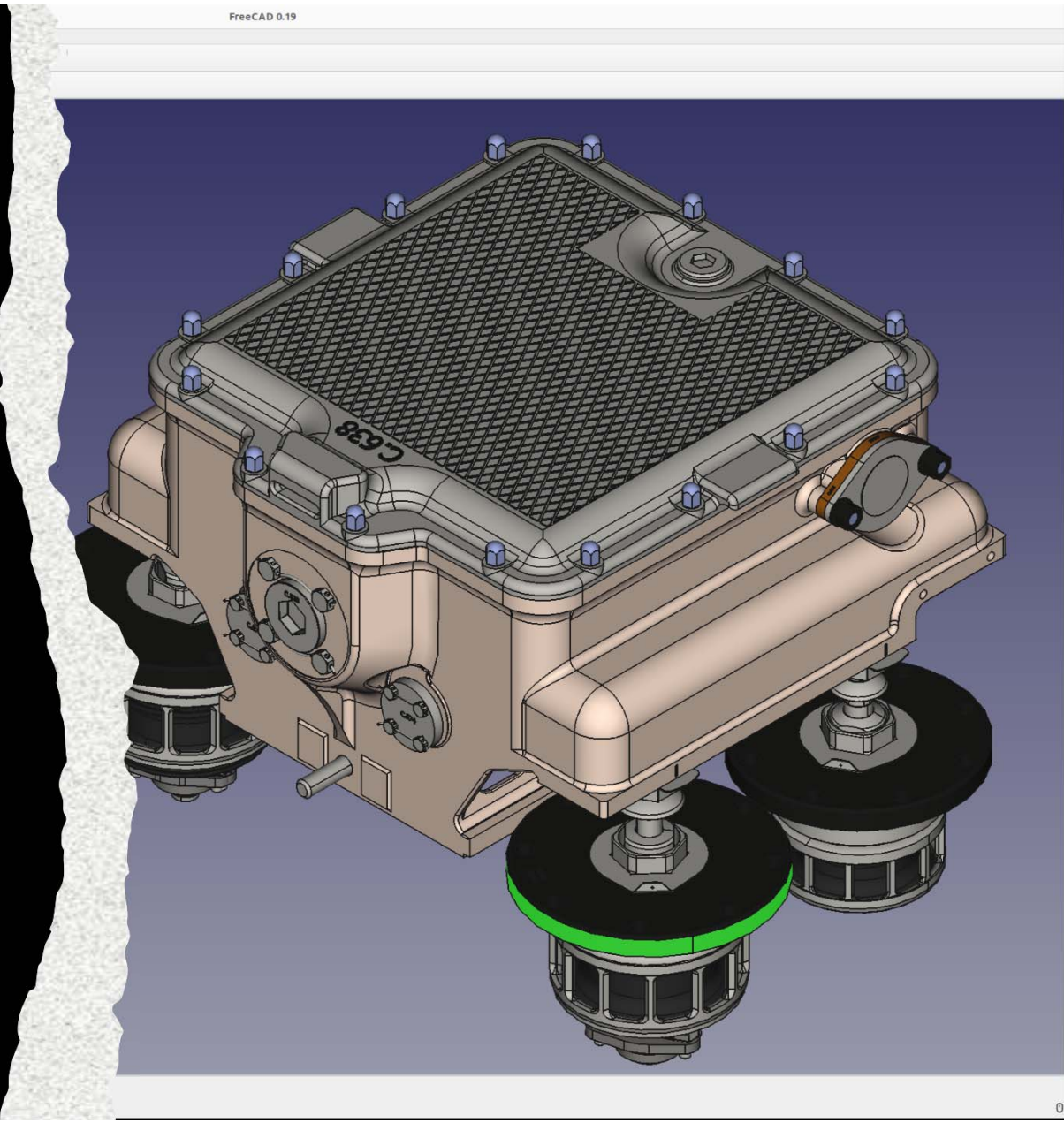
GS0 Paper 403 Indicator Diagram for Caprotti

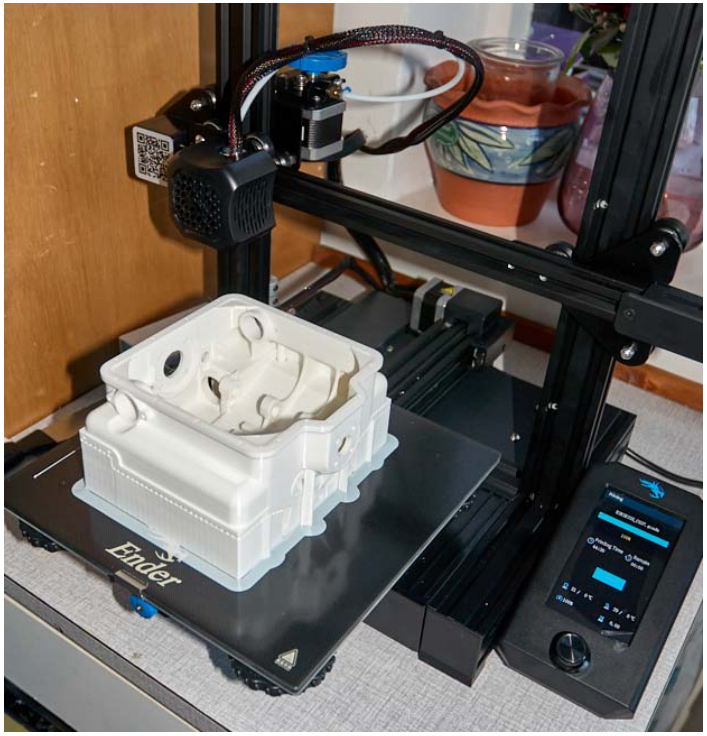
G Shirley, 2023-05-21T10:08:24.776

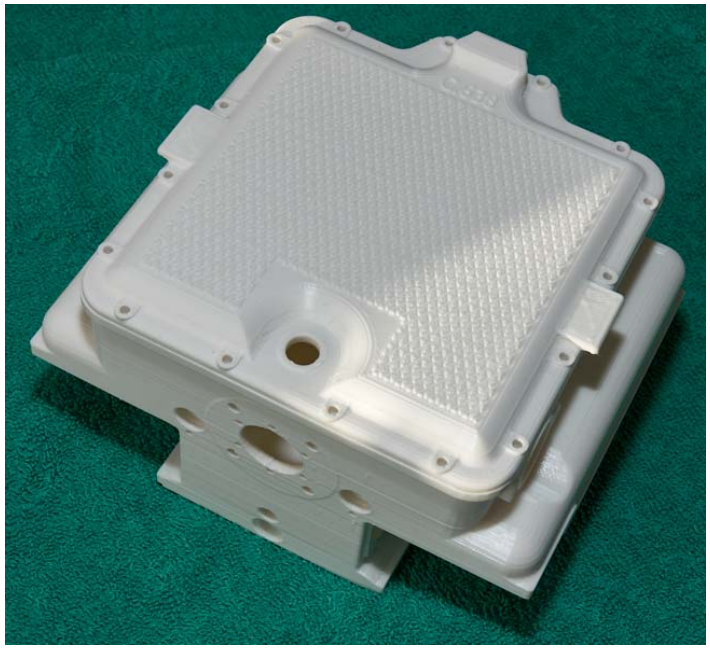


British Caprotti Type 2C0

3D CAD
Solid Model





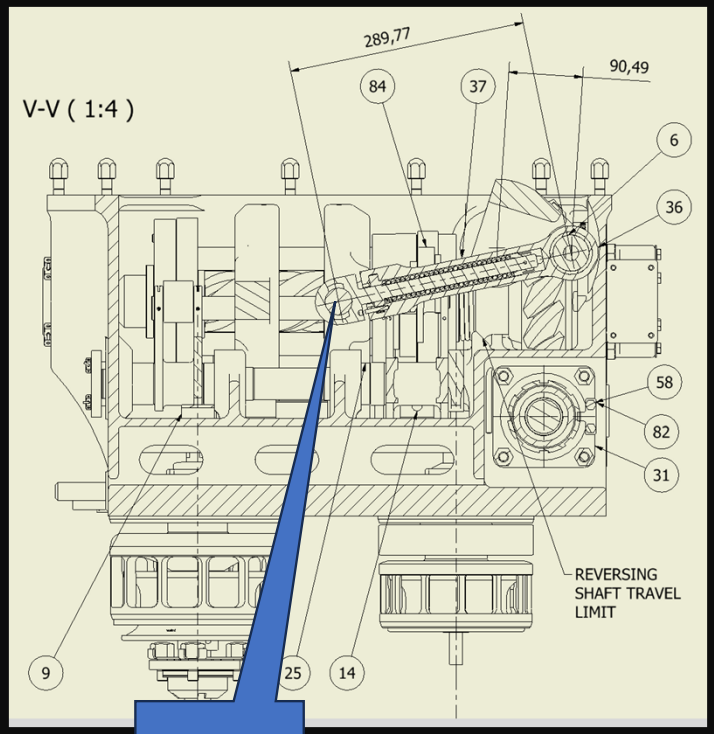


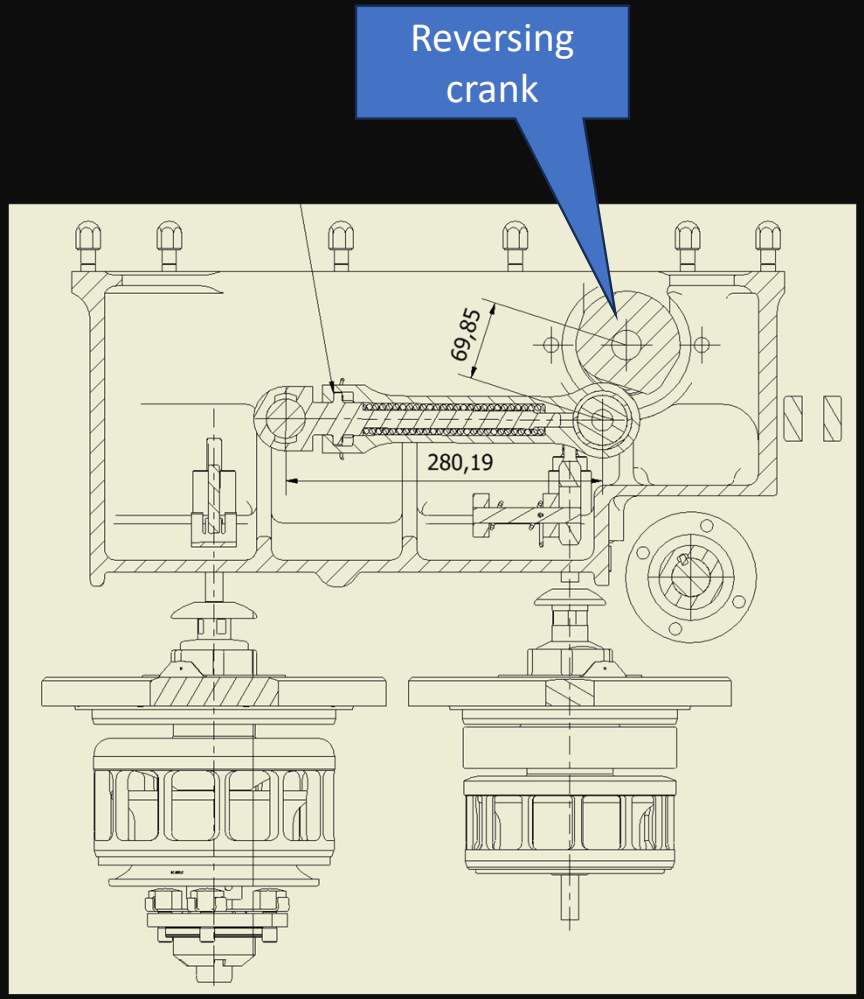
Today – Complexity costs nothing

Video of Cam movement

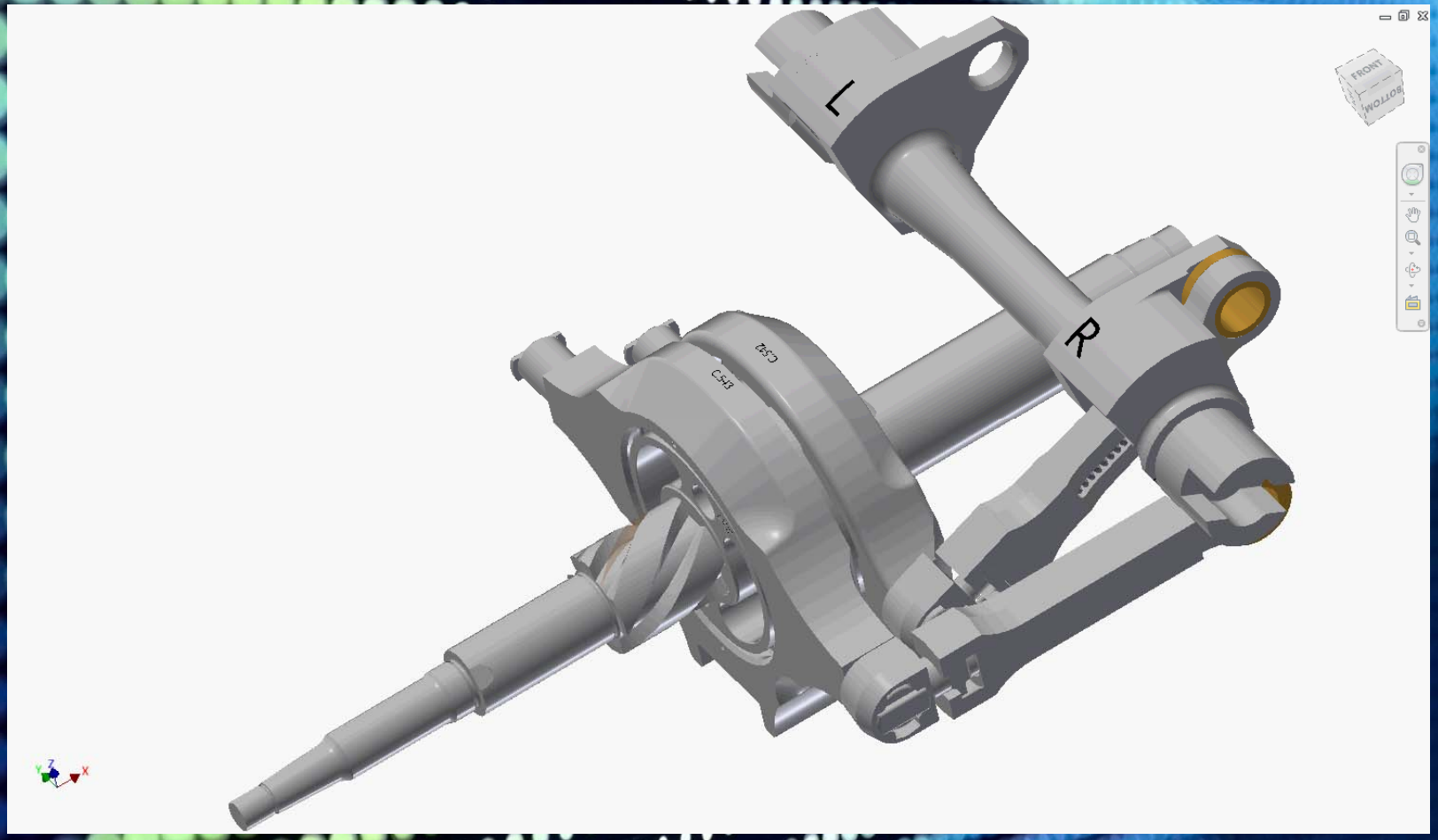
- Caprotti is simple to understand in three steps.
- Linkages from drivers controls give collar positions.
- Collar position translation to angular position.
- Cam movement – analogue computing
- Exhaust valve is an OR Gate function
- Inlet valves are an AND Gate function

Linkages from Reversing crank to scroll Nut

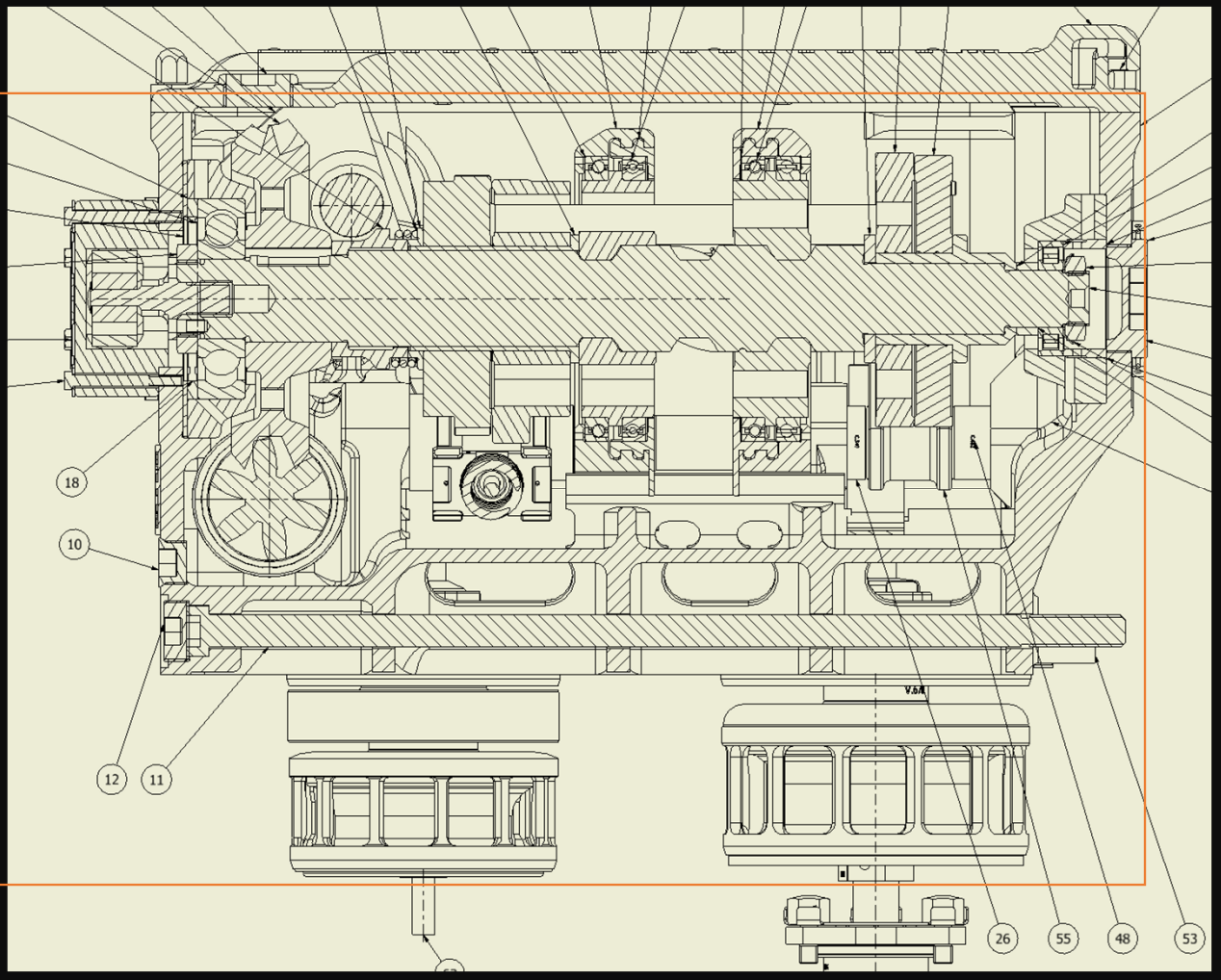




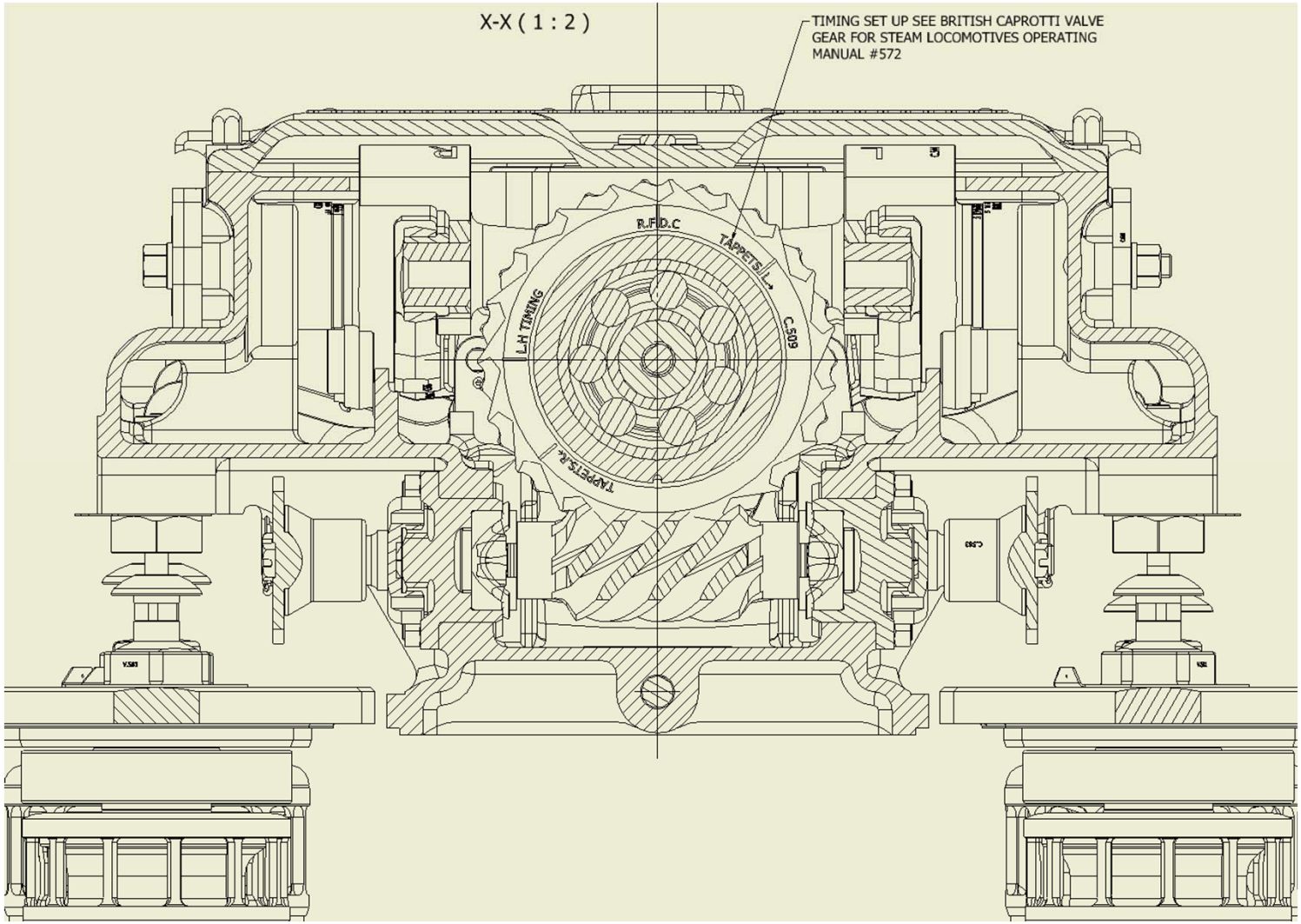
Video of linkage operation

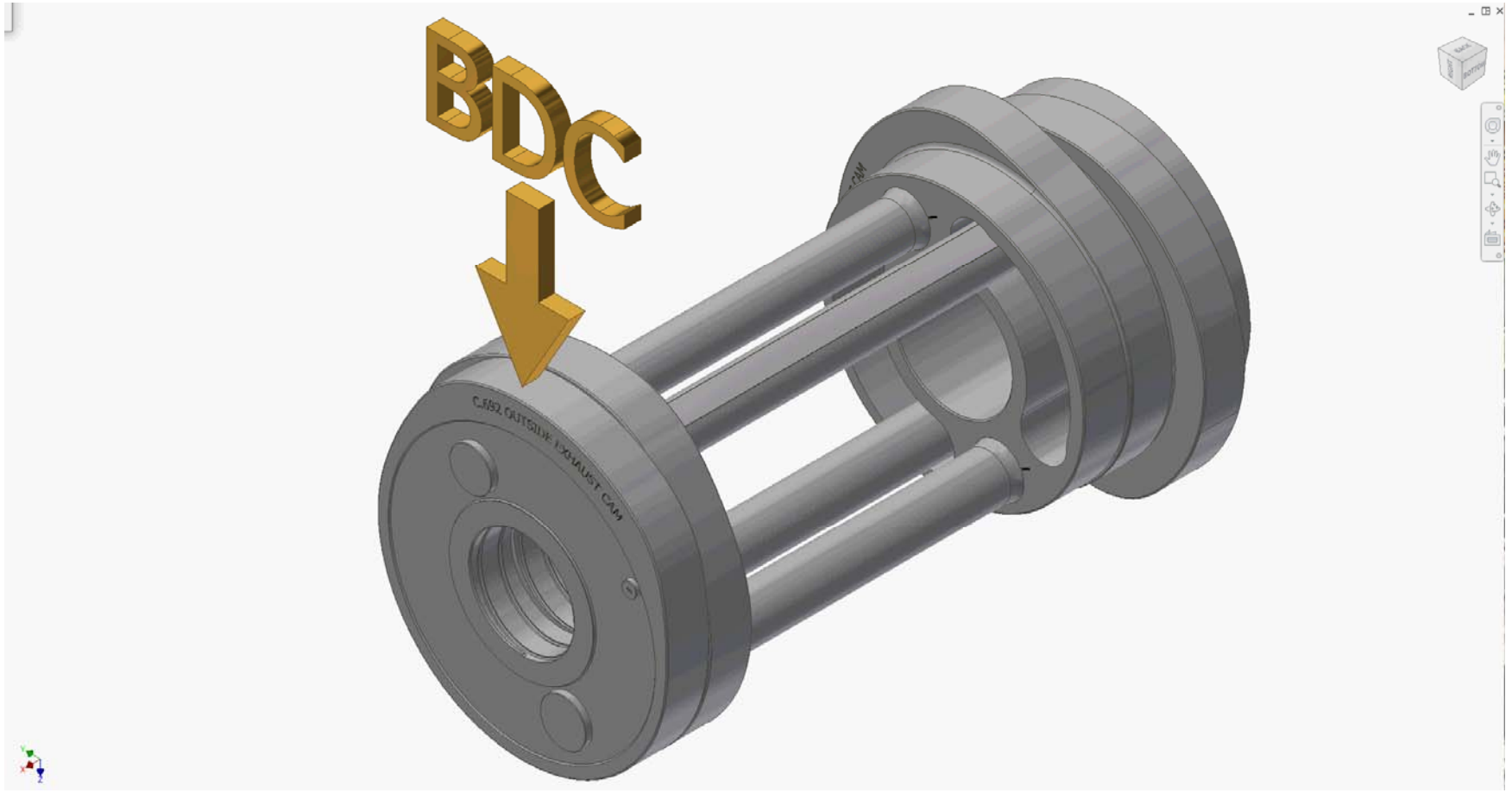


Section on Cam shaft



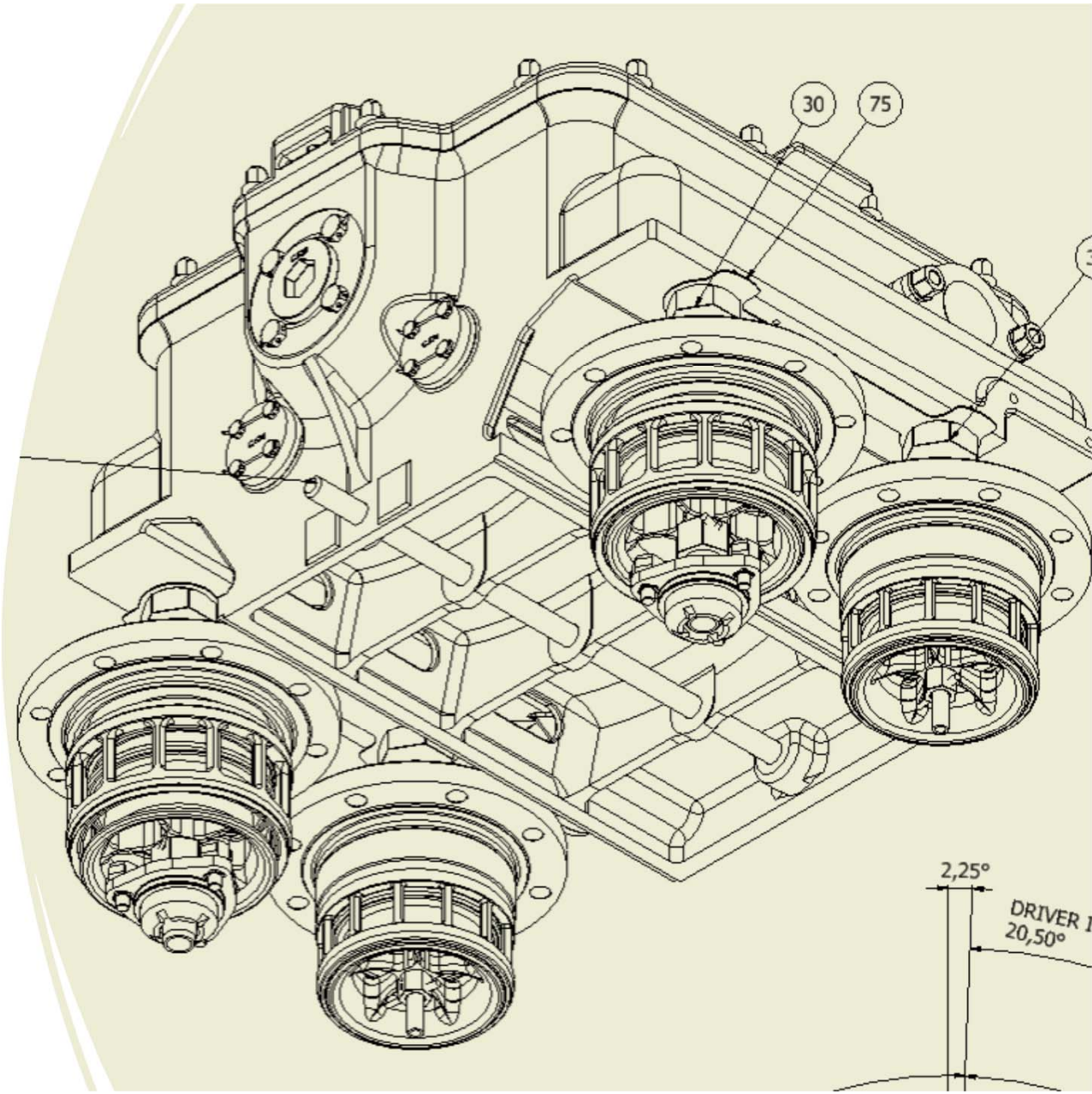
Section showing worm drive



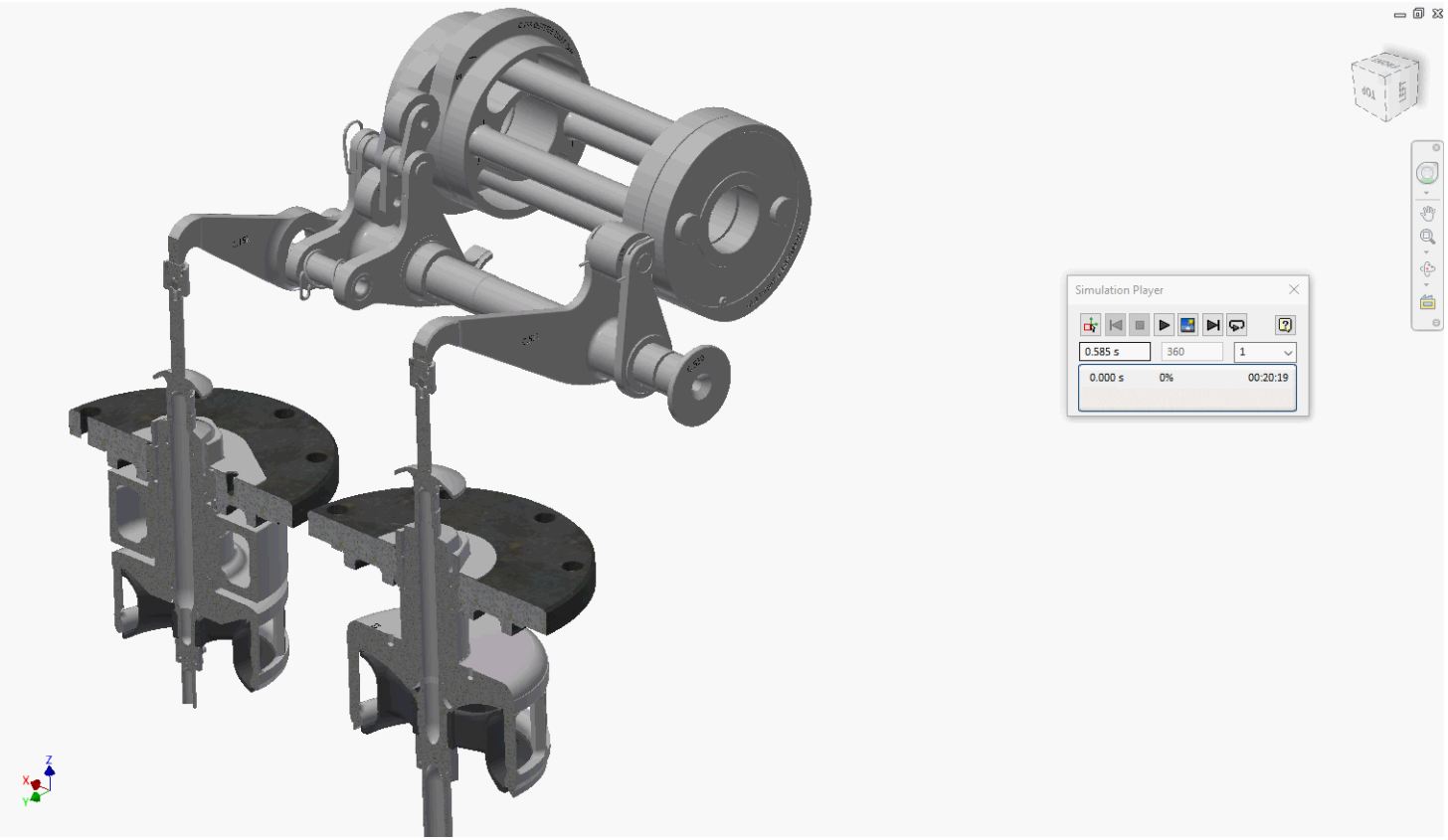

BDC

Poppet valves

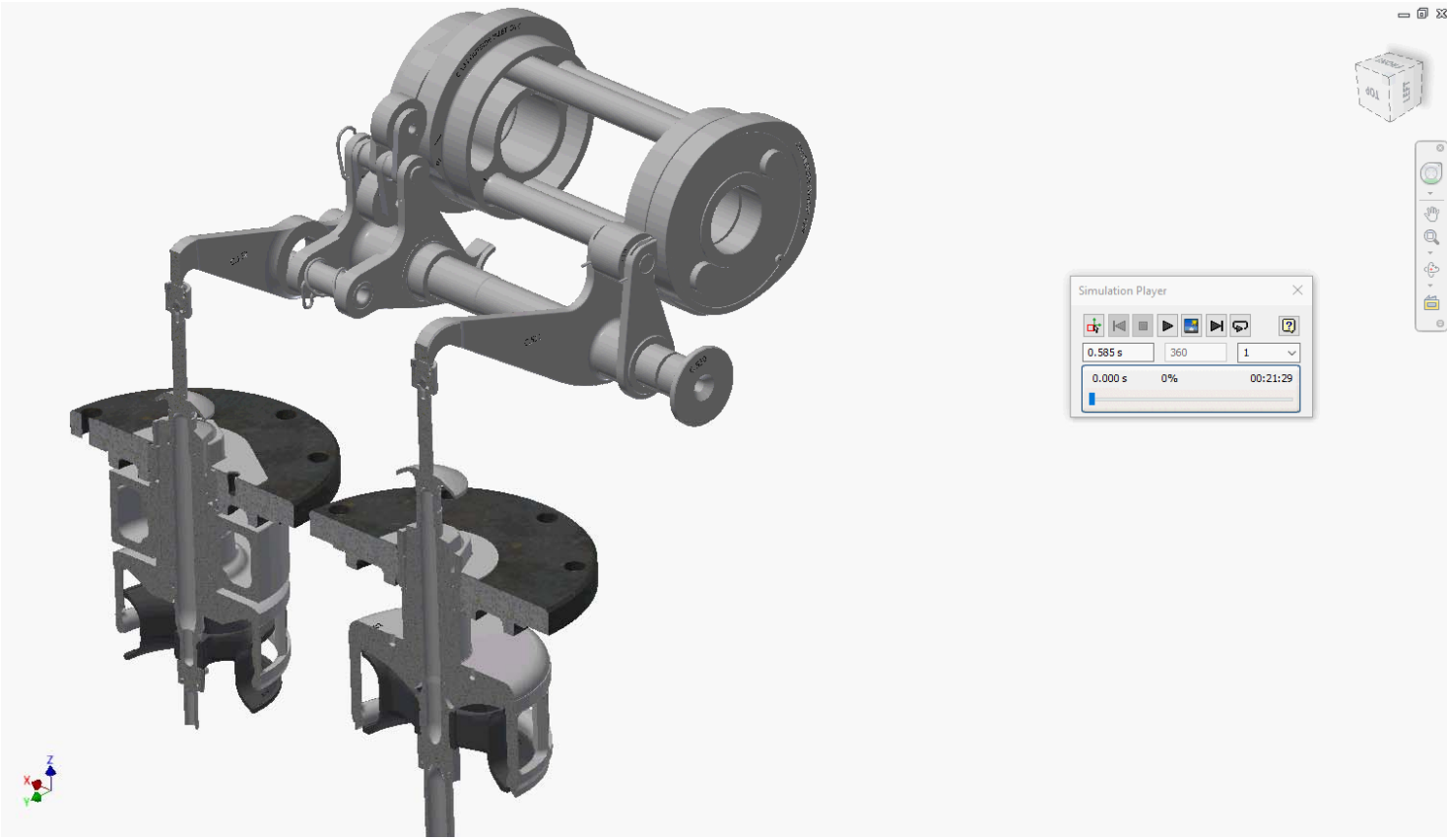
- Why Poppet valves are necessary.
- 1. Very high superheat +400 Degree C makes lubrication difficult due to the oil cracking -carburizing.
- 2. Valve mass reduction of double beat poppet valve moving parts (4 kg) compared to piston valve (100 kg) of the same flow capacity.
- 3. Reduction in valve travel. Piston valves are about 200 mm, Poppet valve travel is 1/8th the valve diameter or about 20 mm.



Short cut off

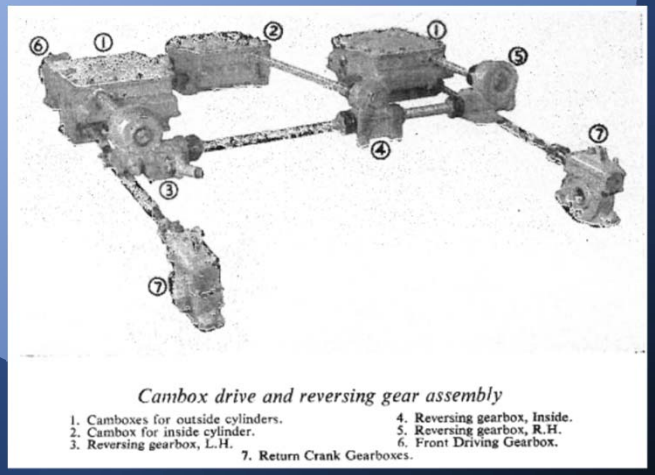


Long cut off



British Caprotti in the UK

British Caprotti in the UK



Cambox drive and reversing gear assembly

1. Camboxes for outside cylinders.
2. Cambox for inside cylinder.
3. Reversing gearbox, L.H.
4. Reversing gearbox, Inside.
5. Reversing gearbox, R.H.
6. Front Driving Gearbox.
7. Return Crank Gearboxes.

BR Reaction

BULLETIN No.15

THE BRITISH TRANSPORT COMMISSION

Performance and Efficiency Tests

BRITISH RAILWAYS STANDARD CLASS 8

3 CYL 4-6-2 EXPRESS PASSENGER

STEAM LOCOMOTIVE No. 71000

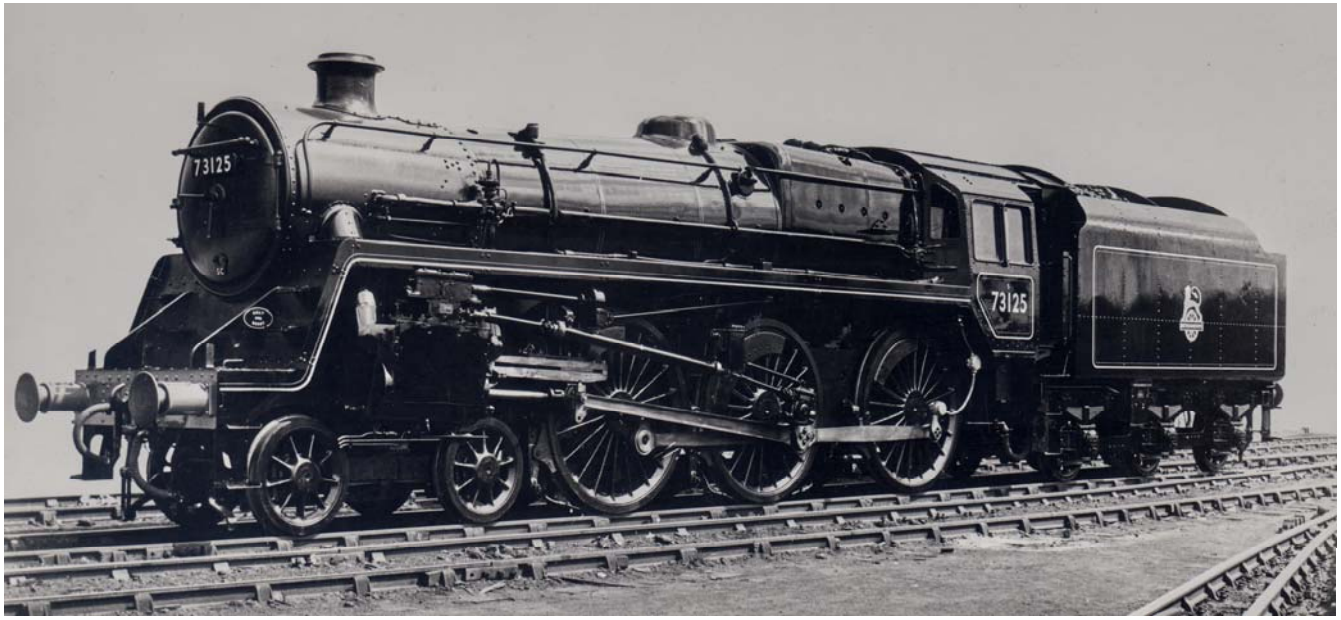
1957

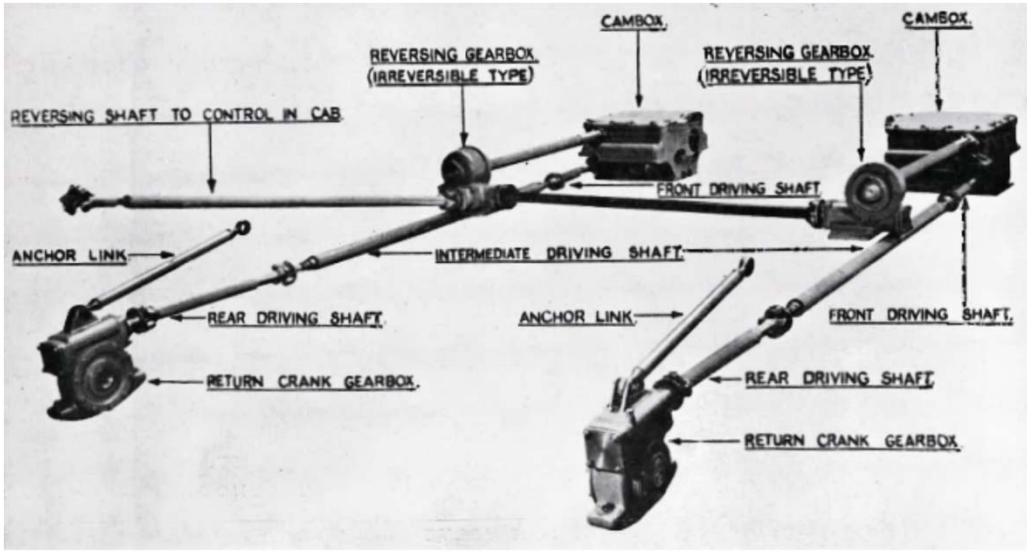
1. INTRODUCTION

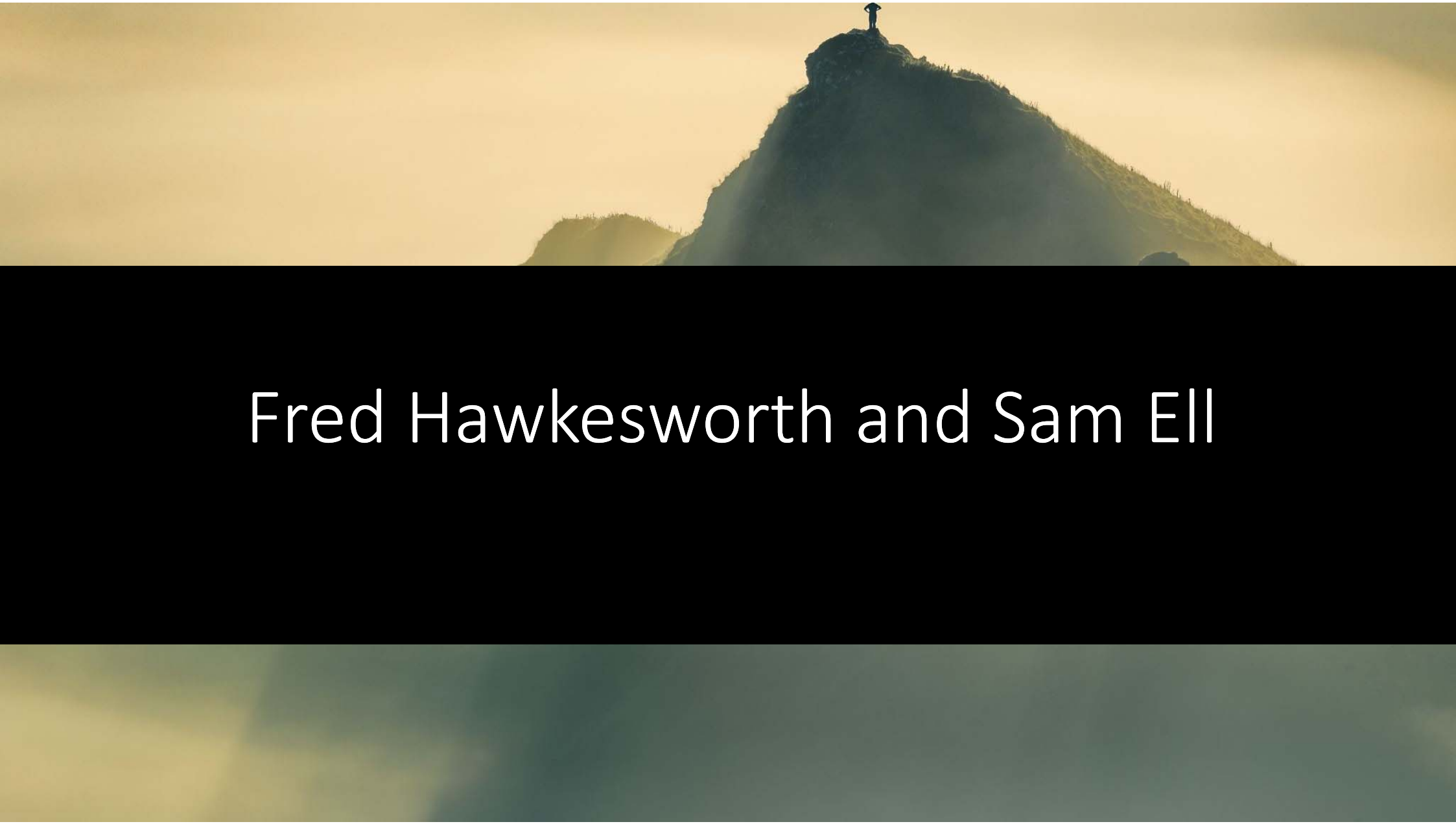
The subject of this Bulletin is the British Railways Standard Class 8 Express Passenger Locomotive No. 71000. Besides having several features not previously incorporated in British Railways Standard locomotives - of which the most noteworthy is steam distribution by poppet valve gear - it represents the ultimate stage of development of the steam locomotive in this country.

Minimum specific steam consumptions do not occur in the very early cut-off range, which corresponds with low steam rates. This accords with the conventional pattern of the steam engine and gives to the Willans' lines their typical form in the low steam rate range. At the extreme end of this range, however, the specific steam consumptions produced by the tests are the least reliable because of the erratic behaviour of the cylinder relief valves which were fitted. Specific steam consumptions with the design of British-Caprotti gear provided are generally lower than obtainable with the normal piston-valve gear and maximum economy is sustained over a wider range of working.

British Caprotti in the UK







Fred Hawkesworth and Sam Ell

GWR 1000 Class

From Wikipedia, the free encyclopedia

For other GWR engine classes called 'County', see GWR County Class.

The Great Western Railway **1000 Class** or **County Class** was a class of 4-6-0 steam locomotive. Thirty examples were built between 1945 and 1947, but all were withdrawn and scrapped in the early 1960s. A replica locomotive is under construction.

Background [edit]

These locomotives were the final and most powerful development of the two-cylinder Saint Class introduced in 1901 and included several features that had already been used on the successful Modified Hall class.[2]

The Chief Mechanical Engineer of the GWR Frederick W. Hawksworth had hoped to design a new 4-6-2 (Pacific) express locomotive for post war traffic, when he took up office in 1941 but had been prevented by the war from doing so.[3] This scheme was not entirely dead in 1945 when he was given the authority to build another batch of mixed-traffic 4-6-0s. Rather than build more examples of existing designs, Hawksworth introduced the County Class as a testbed for a number of the ideas he hoped to incorporate into the Pacific at a later date.[4] Hawksworth was not subsequently allowed to build his Pacific, as there was no need for further express passenger locomotives.

Design [edit]

In addition to the innovations already adopted for the Modified Hall class, the new class contained several further changes from usual Great Western practice including the use of double chimneys on certain members and a high boiler pressure of 280psi (although this was later lowered in an attempt to

GWR 1000 "County" class

1013 *County of Dorset* at Gloucester Eastgate railway station, 1953.

Type and origin	[hide]
Power type	Steam
Designer	Frederick Hawksworth
Builder	GWR Swindon Works
Order number	Lots 354, 358
Build date	August 1945 – April 1947
Total produced	30
Specifications	[hide]
Configuration:	
• **Whyte**	4-6-0
• **UIC**	2'Ch2

Some of the early design studies for what became the County included outside Walschaerts valve gear which would have been a major break from traditional GWR designs. In the event the standard inside Stephenson link motion of the Churchward and Collett two cylinder classes was used. The GWR 1500 Class, also designed by Hawksworth, used outside Walschaerts[i] as did the steam railcar units designed under Churchward and the narrow gauge Vale of Rheidol 2-6-2T.

WR County Class 4-6-0

Meeting with Ell 6 June 1955 at which outline proposals made.

Letter to Ell dated 7 June 1955 confirming details and listing drawings needed.

Consignment Note dated 4 July 1955 covering drawings supplied by Swindon re 1009.

Memo Worcester – London dated 21 July 1955 covering preliminary print off Drg 10121

Technical proposal dated 26 July 1955.

Letter from Ell dated 29 July 1955 advising steam rate of 25,000 lb/hr at 250 psi and 720 degrees F

Proposal to Smeddle dated 22 September 1955

1009	*County of Carmarthen*	December 1945	February 1963	Swindon Works

What was missed…

25/1.

W.R. County (1000) Class Locomotives.

VALVE SIZES

1. General Data.

Boiler Pressure	=	250 lbs/□" *
Wheel Dia	=	6'-3"
Speed (assumed)	=	85 m.p.h (380 r.p.m)
Cylinders (2)	→	= 18½ dia x 28 Stroke
Boiler Steaming Capacity	=	25000 lbs/hr *
Steam Temp.	=	420°F *

* Information from W.S.L., see letter 27-4-55.

2. Inlet Valve Sizes.

Steam Consumption per valve/hr. = 25000 / 4 = 6250 lbs/hr.

" " " Rev. = 6250 / 60 x 380 = .274

Spec Vol assuming steam chest pressure = 250 lbs/□" abs. = 2.734

Steam Consumption per Rev = .274 x 2.734 = 0.75 Cu ft.

Sp. Vol = 4.64 Cu ft.

Theoretical Cut-off = 0.75 / 4.64 = 16%

Assuming 13° 10' effective opening & steam at 200 ft/sec

13° 10' = 43° i.e. 43/360 rev = .1195 Rev.

∴ Time of admission = .1195 x .158 = .0189 secs

Consumption per rev = 0.75 Cu ft.

" " /sec = .75 / .0189 = 39.7 Cu ft/sec

25/2.

W.R. County (1000) Class (Cont.)

Valve Sizes (Cont.)

∴ Area Required = 39.7 x 144 / 200 = 28.6 sq ins

Nearest size = 6¼" dia Valve = 27.54 sq ins

∴ Standardise on L.M.R. Class 5 sizes

i.e. INLET	=	6¼" DIA.
EXH.	=	7" DIA.

CALCULATION

WR County (1000) Class - POPPET VALVE SIZES

Advanced Steam Traction Trust

https://en.wikipedia.org/wiki/GWR_1000_Class

REF: C12 Historical Model Railway Society - ALE Technical Data Valve Sizes calculation pack Page 25. Author L T Daniels 8th August 1955.

1013 *County of Dorset* at Gloucester Eastgate railway station, 1953.

1. 0 General Data

$Boiler\_Pressure := 250\ psi$

$Wheel\_Dia := 6\ ft + 3\ in$

$Speed := 85\ mph$

$Cylinder\_Dia := 18.5\ in$

$Cylinder\_Stroke := 28\ in$

$Boiler\_Steam\_Capacity := 25000\ \frac{lb}{hr}$

$Steam\_temp := 720\ °F$

Ref: Information from S.O Ell, Swindon, see letter 29 July 1955

$No\_Cylinders := 2$

Calculated Data

$$Speed\_crank := \frac{Speed \cdot 2 \cdot \pi}{Wheel\_Dia \cdot \pi}$$

$Speed\_crank = 381\ rpm$

2.0 Inlet Valve Sizes.

$$Steam\_consumption\_per\_valve\_per\_hr := \frac{Boiler\_Steam\_Capacity}{No\_Cylinders \cdot 2}$$

$$Steam\_consumption\_per\_valve\_per\_hr = 6250 \ \frac{lb}{hr}$$

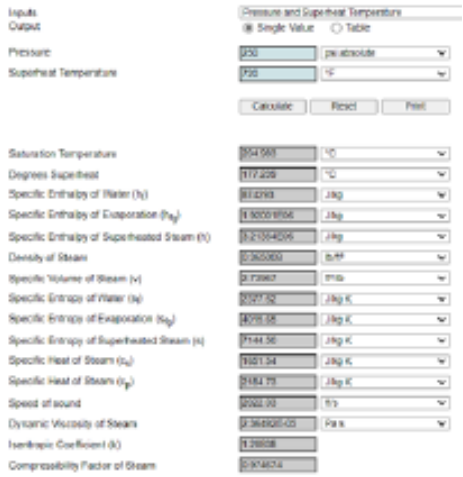
$$Steam\_consumption\_per\_rev := \frac{Steam\_consumption\_per\_valve\_per\_hr \cdot 2 \cdot \pi}{Speed\_crank}$$

$$Steam\_consumption\_per\_rev = 0.273 \ lb$$

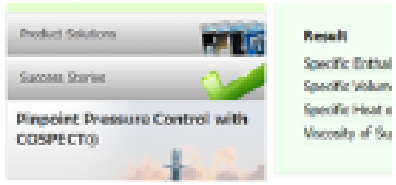
$$Specific\_Volume := 2.73967 \ \frac{ft^3}{lb}$$

Superheated steam specific volume assuming steam chest at boiler pressure and 720 deg F superheating.
https://www.spiraxsarco.com/resources-and-design-tools/steam-tables/superheated-steam-region#article-top

$$Specific\_Volume := 2.727 \ \frac{ft^3}{lb}$$ Figure used by ALE Steam Table.



$$Specific\_Volume := 2.727 \frac{ft^3}{lb}$$ Figure used by ALE Steam Table.



$$Steam\_comsumption\_vol\_per\_rev := Steam\_consumption\_per\_rev \cdot Specific\_Volume$$

$$Steam\_comsumption\_vol\_per\_rev = 0.75\ ft^3$$

$$Cylinder\_volume := \left(\frac{Cylinder\_Dia}{2}\right)^2 \cdot \pi \cdot Cylinder\_Stroke \cdot 1.073$$

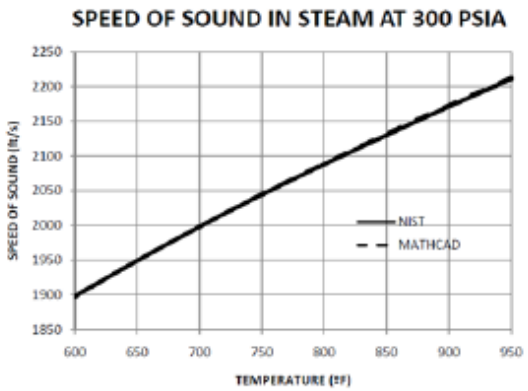
$$Cylinder\_volume = 4.67\ ft^3$$

$$Theoretical\_cut\_off := \frac{Steam\_comsumption\_vol\_per\_rev}{Cylinder\_volume}$$

$$Theoretical\_cut\_off = 16\ \%$$

Assuming 13.5% as effective opening and steam at 200 ft per sec

$Steam\_speed := 200\ \frac{ft}{s}$



Steam speed is defined as the piston area divided by the valve area multiplied by the piston speed. 2000 ft/s is critical - choking of flow. They assumed about 1 tenth for steam speed.

REF:THE SPEED OF SOUND IN STEAM
Edwin G. Wiggins,Webb Institute in Glen Cove, NY.

Calculate the cut off positions.

$Cut\_off\% := 13.5$

$\theta := \operatorname{acos}\left(2 \cdot \frac{Cut\_off\%}{100} - 1\right)$ $\theta = 136.9\ deg$

Angle at cut off from rear dead centre

$\alpha := 180\ deg - \theta$ $\alpha = 43.1\ deg$

Angle at cut off from forward dead centre

$Time\_Steam\_Admission := \frac{\alpha}{Speed\_crank}$

$Time\_Steam\_Admission = 0.0189\ s$

$$Steam\_consumption := \frac{Steam\_comsumption\_vol\_per\_rev}{Time\_Steam\_Admission}$$

$$Steam\_consumption = 39.5 \frac{ft^3}{s}$$

$$Valve\_Area\_required := \frac{Steam\_consumption}{Steam\_speed}$$

$$Valve\_Area\_required = 28.5\ in^2$$

$$Poppet\_Area_{6.25} := 27.54\ in^2$$

Nearest standard poppet valve

Therefore standardise on L.M.R Class 5 locomotive.

$$INLET := 6.25\ in$$
$$EXHAUST := 7\ in$$

BRITISH-CAPROTTI VALVE GEAR
VALVE AREAS.

5½" - 9½" diameter.

	INLET					EXHAUST
Valve Size.	Max. Area through Valve sq. ins.	Area 51/64" Lift. sq. ins.	Area 57/64" Lift. sq. ins.	Area 15/16" Lift. sq. ins.	Area 1" Lift. sq. ins.	1.5/64" Lift. Area sq. ins.
5½"	21.44	-				21.44
6½"	27.54	-				27.54
7"	32.47	-				32.47
7½"	38.87	38.25				38.87
8½"	45.12	41.7	46.58			45.12
8½"	48.023	42.5	47.6	50.54		48.023
8½"	50.99	44.19	49.4	52.0		50.99
9"	54.81	45.46	50.8	53.4	57.04	54.81
9½"	57.5	46.7	52.2	54.95	58.6	57.5

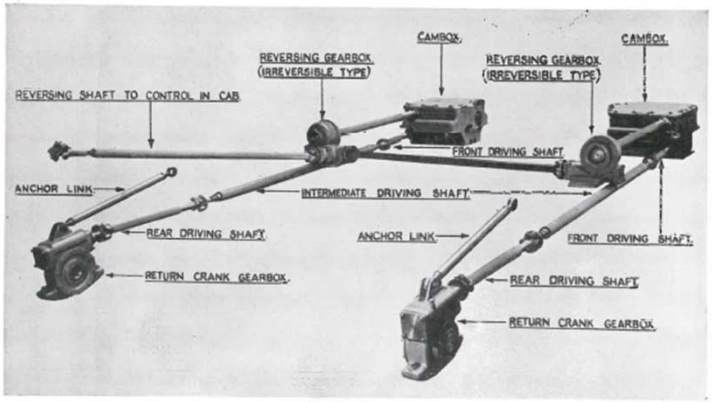
THIRTY BRITISH RAILWAYS' STANDARD CLASS 5 LOCOMOTIVES

FITTED WITH

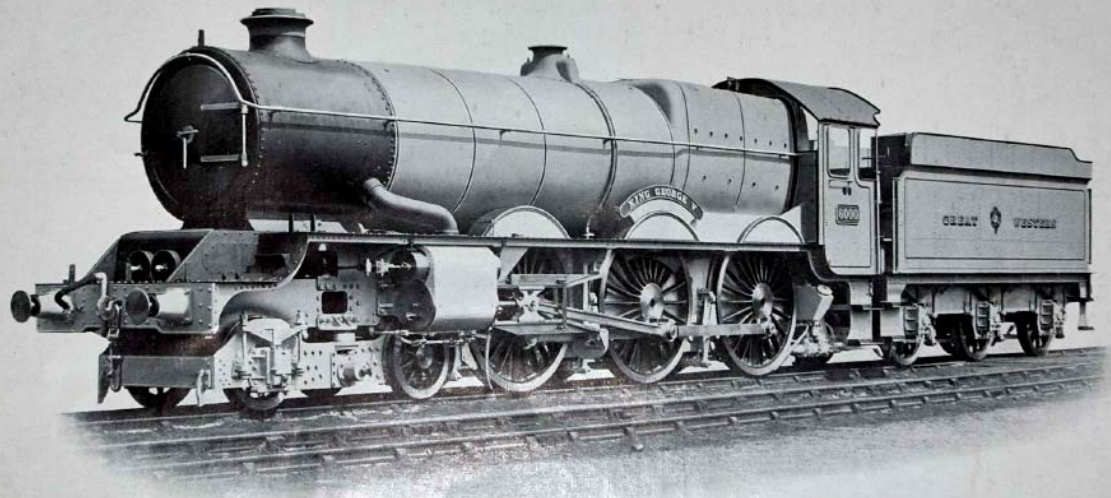
BRITISH-CAPROTTI POPPET VALVE GEAR

British Railways Standard Class 5 locomotive fitted with rotary cam gear

A RECENT development in British Railways locomotive design is the fitting of 30 class "5" mixed-traffic engines with British-Caprotti valve gear. Except for the replacement of the Walschaerts valve gear, the latest engines of this class are basically similar to those introduced early in 1951, and described in our issue of May 4 of that year. The latest class "5" locomotives, which were built at Derby Works, have the same tractive effort, and weigh, in working order, on the average four to six tons heavier; there is also a slight increase in grate area. The fitting of rotary cam gear should increase both the thermal and mechanical efficiencies of the locomotives; no doubt the decision to fit British-Caprotti valve gear has been influenced by the results obtained by the class "8" 4-6-2 locomotive *Duke of Gloucester*, which has been the subject of extended tests on the British Railways. The dome-type regulator incorporates a special valve which automatically admits saturated steam to the bottom of the valve spindles and lifts the valves into their working position before the main steam supply is admitted and also provides the closing force during running. Other features include rectangular section coupling rods in place of girder section, hinged cab front windows, and gangway doors fixed on the cab.



General arrangement of the gear



4-6-0 4-Cylinder Express Locomotive.
Great Western Railway.

Designed by C. B. Collett, O.B.E.,
Chief Mechanical Engineer.

Fitted with METCALFE'S PATENT EXHAUST STEAM INJECTOR.

Poppet valves on the King Class

WR King Class 4-6-0

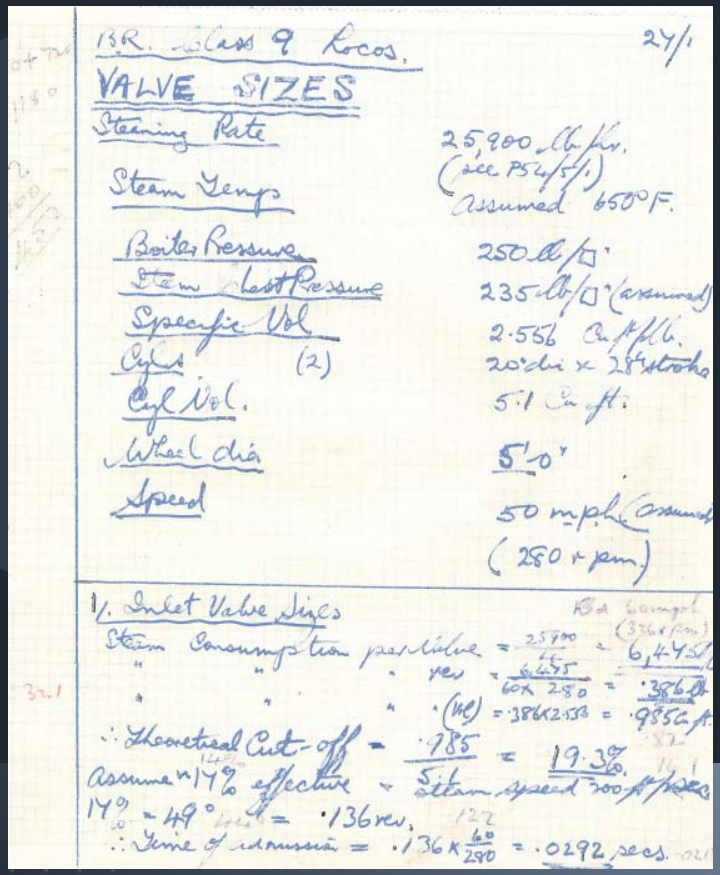
Internal memo dated 7 February 1957 discusses the "front heavy" nature of these locos and that Caprotti could be beneficial because it would be lighter.

London requests more information on 8 February 1957, Worcester replies on 11th, London asks for a proposal on 12th, Worcester replies on 13th giving general outline.

Proposal to Smeddle dated 7 June 1957 enclosing drawing 10125

GS0

BR Class 9 – Poppet Valve Calculations



BR. Class 9 Locos. 24/1

VALVE SIZES

Steaming Rate	25,900 lb/hr. (see P54/5/1)
Steam Temp	Assumed 650°F.
Boiler Pressure	250 lb/□"
Steam Chest Pressure	235 lb/□" (assumed)
Specific Vol	2·556 Cu ft/lb.
Cyls (2)	20" dia x 28" stroke
Cyl Vol.	5·1 Cu ft.
Wheel dia	5'-0"
Speed	50 m.p.h. (assumed) (280 r.p.m.)

1/. Inlet Valve Sizes

Steam Consumption per Cylinder = 25900/4 = 6,475 lb/hr (376 r.p.m.)

" " per rev = 6,475/60 × 280 = ·386 lb

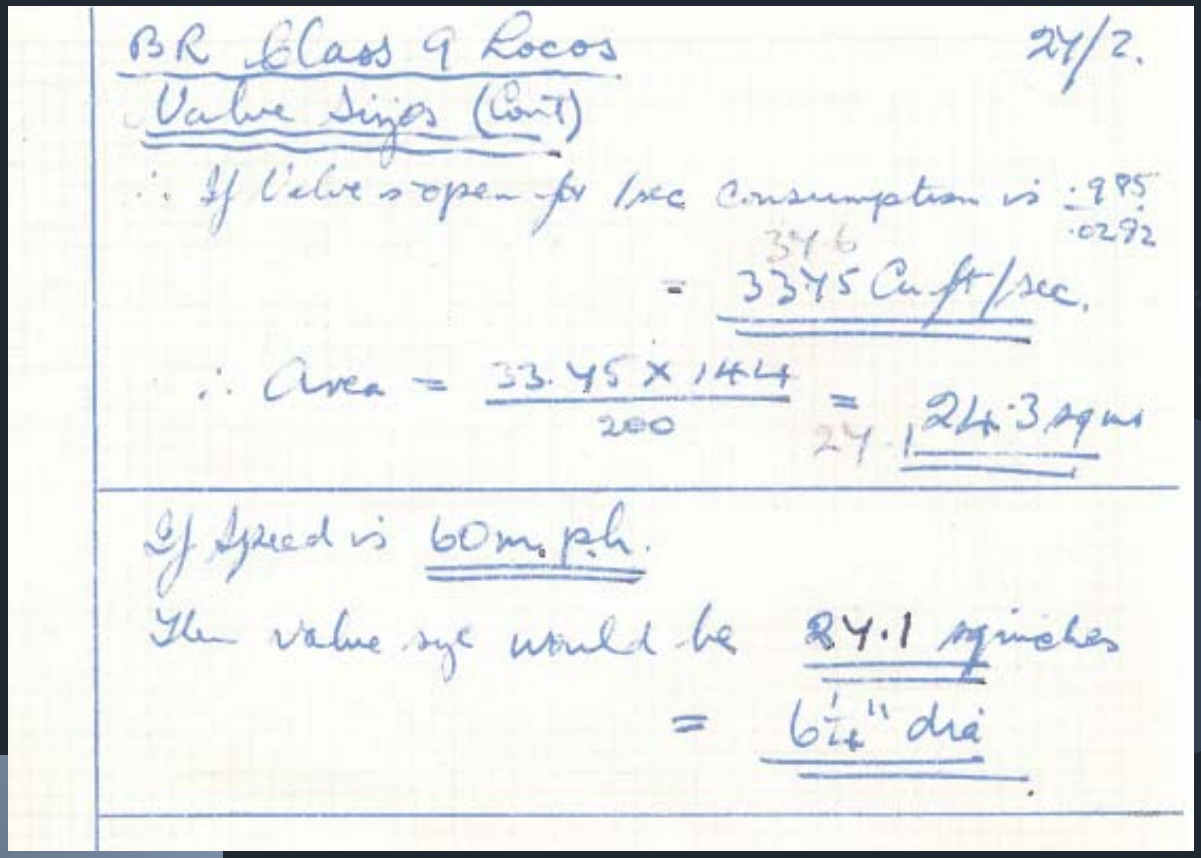
" " " (Wt) = ·386 × 2·556 = ·985 Cu ft

∴ Theoretical Cut-off = ·785/5 = 19·3%

Assume 14% effective = Steam speed 300 ft/sec

14% = 49° = ·136 rev.

∴ Time of admission = ·136 × 60/280 = ·0292 secs.



BR Class 9 Locos 24/2.

Valve Sizes (Cont)

∴ If Valve is open for 1 sec Consumption is ·985/·0292

= 34·6 = 3345 Cu ft/sec.

∴ Area = 33·45 × 144/200 = 24·1 = 24·3 Sq ins

If Speed is 60 m.p.h.

Then valve size would be 24·1 sq inches

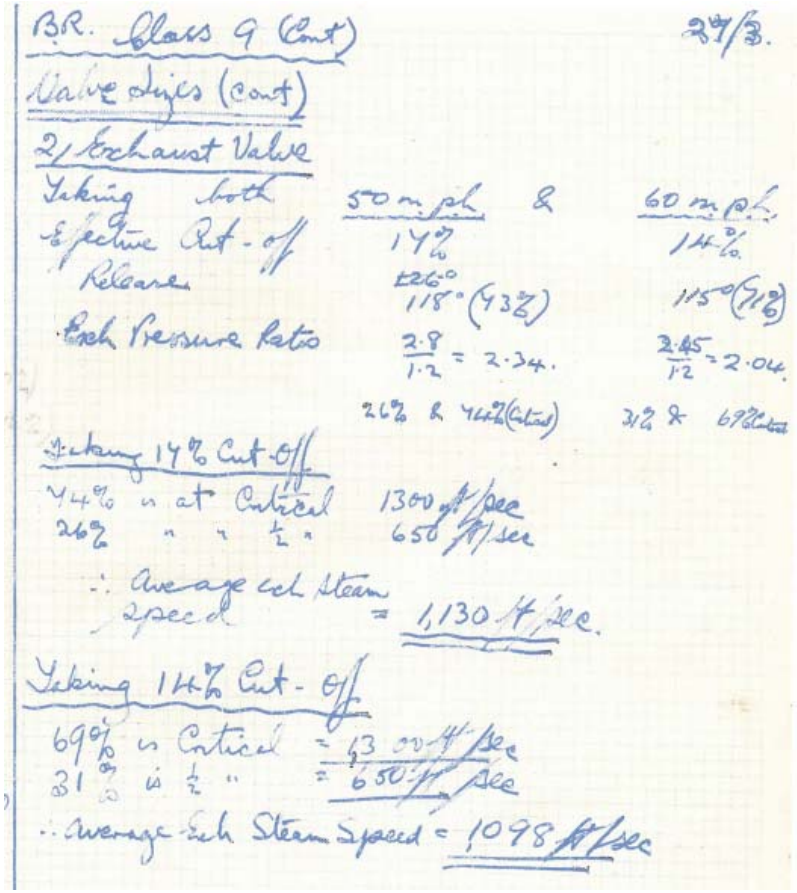
= 6 1/4" dia

GS0 ALE VALVE AND TAPPET CAM CALC BOOK

G Shirley, 2023-05-10T20:47:01.220

GS0

BR Class 9 – Poppet Valve Calculations



BR. Class 9 (Cont) 24/3.

Valve dyes (cont)

2/ Exhaust Valve

	50 m.p.h. &	60 m.p.h.
Taking both Effective Cut-off	14%	14%
Release	126°	
	118° (43%)	115° (41%)
Exh Pressure Ratio	2.8/1.2 = 2.34.	2.45/1.2 = 2.04.
	26% & 44½% (Critical)	31% & 69% Critical

Taking 14% Cut-off

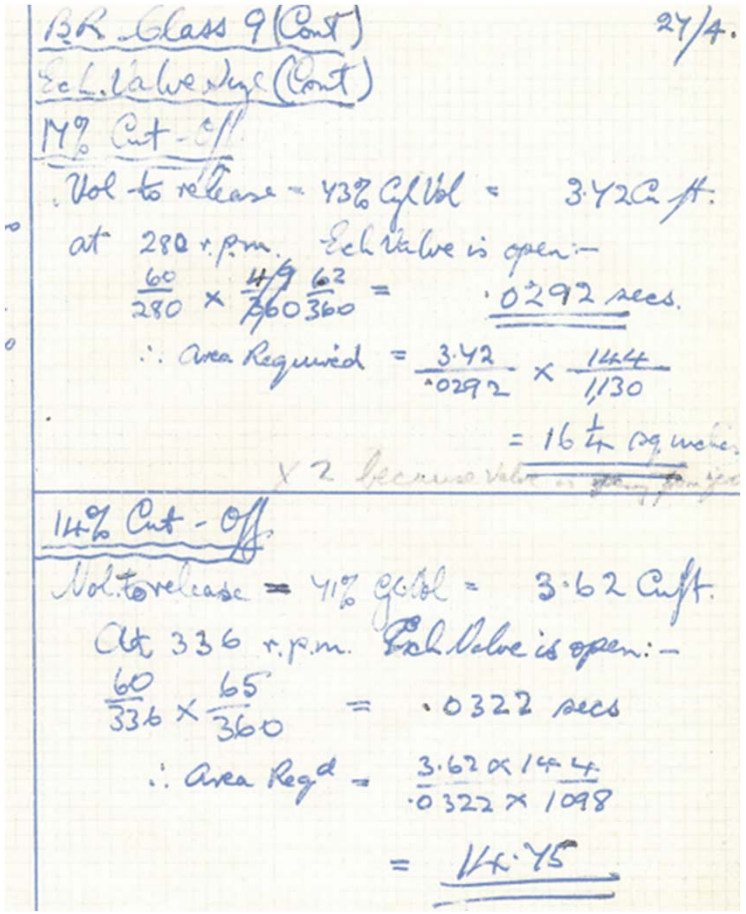
44½% is at Critical 1300 ft/sec
26% " " ½ " 650 ft/sec

∴ Average exh steam speed = 1,130 ft/sec.

Taking 14% Cut-off

69% is Critical = 1300 ft/sec
31% is ½ " = 650 ft/sec

∴ Average Exh Steam Speed = 1098 ft/sec



BR Class 9 (Cont) 24/4.

Exh Valve dyes (Cont)

14% Cut-off

Vol to release = 43% Cyl Vol = 3.42 Cu ft.

at 280 r.p.m. Exh Valve is open:-

$\frac{60}{280} \times \frac{4/9}{360} \frac{62}{360}$ = .0292 secs.

∴ Area Required = $\frac{3.42}{.0292} \times \frac{144}{1,130}$

= 16¼ sq inches.

X 2 because valve on ... [illegible]

14% Cut-off

Vol to release = 41% cyl vol = 3.62 Cu ft.

At 336 r.p.m. Exh Valve is open:-

$\frac{60}{336} \times \frac{65}{360}$ = .0322 secs

∴ Area Reqd = $\frac{3.62 \times 144}{.0322 \times 1098}$

= 14.45

GS0 ALE VALVE AND TAPPET CAM CALC BOOK

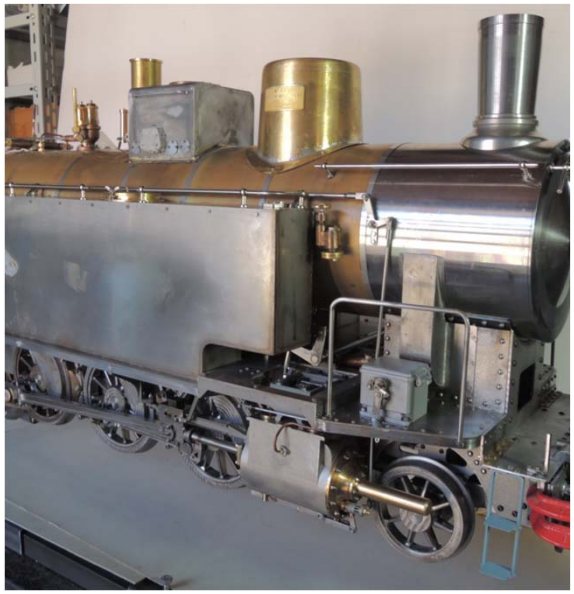
G Shirley, 2023-05-10T20:46:52.149

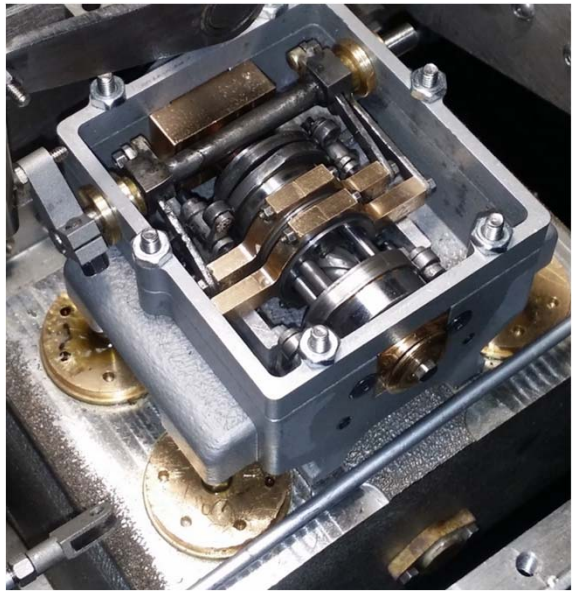
www.ferroviefelettane.it

https://www.youtube.com/watch?v=pDmM4vtjGO8

LOCOMOTIVA FCS400 with Caprotti CP2 cambox

- Alberto in Italy is famous for model engineering skills. Here seen on his Big Boy.





Thank you

Questions

Referenced documents

Hugh Philips archive HMRS

Beardmore Built – Ian Johnston

2023 G Shirley