The Strange History of Tank Inerting

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1 The Origins of Tankship Inerting

On the night of February 4th, 1932, the 10,950 dwt Sun Oil tanker BIDWELL was cleaning tanks at Marcus Hook refinery on the Delaware River. She had carried crude oil from Texas to the refinery and was now preparing to take gasoline back. At 12:20 AM, she exploded. The first explosion was followed by three more blasts within 25 minutes. The explosions were heard 20 miles away. 18 crew including the Master were killed. The Master's wife was pulled from the frigid waters by a Sun Oil employee who swam to her rescue.

Tanker explosions were nothing new. They were by far the most frequent kind of non-war tanker casualty. The first known conversion of a wooden sailing ship to carry oil in bulk was the Charles. In 1869, the Charles was fitted with 59 separate tanks. Three years later she caught fire and was lost. Tanker crews knew what to worry about. In a bit of gallows humor, the crew of the first successful engine-driven, ocean-going bulk oil tanker, the Gluckauf, nicknamed her the Fleigauf (or Blow Up). The Gluckauf did not blow up, but her sister ship the Vorwarts lasted only four years before she caught fire at Savona, and had to be sunk.

Table 1 shows a horribly incomplete list of pre-WW II, non-war tanker fires and explosions.

Table 1: Some pre-WW II, non-War Tanker Explosions

Year	Ship	Dead	Vol(m3)	Synopsis
1872	charles			sail conversion, 59 leaking tanks, lost by fire
1888	fergusons			steam conversion, 'blown to pieces' in Rouen
1890	vorwarts			Gluckauf sister, fire at Savona, towed out, sunk
1891	lux	16		fire, and sank, 16 killed, 6 saved
1892	petrolea			struck by lighting, blew up, near Bordeaux, cargo kero
1902	nerite			fire 1902-03 lightening Bulysses in Canal, total loss
1902	bakunin			loaded Callao, fire, Some says repairing
1907	silverlip	5		exp in no 4 tank, Bay of Biscay, spore to uk petrol, sunk 5 dead
1910	manhatten			19100923 sailed from NY to Algiers loaded. Not heard of since.
1911	chesapeake			exp 40.2N,48.4W, ny to algiers, abandoned
1912	spondilus			fire 1912-01-13
1914	kometa	15		tank explosion, 1914-04-26, 15 killed
1915	dakotah			fire 1915-10-03, sank 2.4S116.4E, Balikpapan/Europe benzine
1917	sebastian			explosion, loaded, 1917-05-17
1922	coylet			explosion, loaded, sank off Sand key, 1922-02-08
1926	volga			fire, 1926-01-12, destroyed
1926	phoenix	2		DH,riveted tank leak, explosion Boston, 2 killed, Ludwig hurt
1928	chuky			internal explosion, loaded, sank, 1928-02-15
1932	bidwell	18		tank cleaning, last cargo crude, 18 killed
1933	c. s. petrol	3		internal explosion, sank, 1933-07-14, 3 killed
1934	la crescenta	29		suddenly disappeared, 29 killed

But Sun Oil had had enough. They knew that they could make tankers much safer by *inerting* the cargo tanks The technology was already in use in refineries, and could easily be adapted to tankers.[1] The process consists of diverting a portion of the boiler exhaust gas to a scrubber, which is little more than a large shower which cools the gas and extracts most of the sulfur, and then pumping the combusted, low oxygen gas to the tanks. If the system is properly maintained and operated, the oxygen content in the tank atmosphere will be less than 5%. Normal air is about 21% O2. An oxygen content below 10% will not support combustion regardless of the amount of hydrocarbon vapor in the gas.

Sun Oil knew the system would not have prevented the first BIDWELL explosion. In those days, it was necessary to enter a tank in order to clean it, which would have required purging an inerted tank with fresh air. However, inerting would have made it far more difficult for the fire to spread to the other tanks, and likely prevented the follow-on explosions.

In any event, Sun Oil reacted quickly and aggessively. By the end of 1933, all Sun Oil tankers were fitted with inert gas systems (IGS). This included the Bidwell which survived. The Bidwell was later torpedoed in 1942 while loaded 30 miles east of Cape Lookout by the U-160. The torpedo struck midships, burning oil was spilled on deck and killed the 2nd Mate; but the fire did not spread to the undamaged tanks. The crew was able to put the fire out, and make port under the ship's own power. Sun Oil credits inerting for saving "many lives" on its ships during World War II, but we don't have much in the way of details.[3].[2] The Bidwell ended up being scrapped in 1965 at age 45. Tough ship.

It wasn't long after Sun had implemented inerting before they realized that proper inerting dramatically reduces steel corrosion rates in the cargo tanks. Corrosion is an oxidation process and proceeds much more slowly in an oxygen depleted environment. Sun Oil found that the need for steel renewals was drasticially reduced and in some cases eliminated. Typically, an uncoated ship in clean product service has a service life of about 12 years, and 20-25 years in dirty service, albeit with extensive steel renewals from year 15 on. But the Sun ships were different. The American Sun which had been in clean service for about four years, passed her 16 year survey without any replacement of steel, and her 20 year survey (at which point it had been in clean or partially clean service for 8.5 years) with minimal renewals due to *external* wastage. The Sabine Sun passed her 20 year special survey with no renewals in the cargo spaces. This ship had 2.5 years in clean service and another 7 years in part clean service.[2, page 239]

This was not only an important economic saving, but a big safety and enviromental plus as well. Tank corrosion can easily result in cargo leaking into ballast tanks and/or pump rooms, where it becomes a major hazard. Devanney found that the single biggest cause of tanker spillage was explosions resulting from cargo being where it shouldn't be.[4, page 90]

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[1] In the mid-late 1920's, Chevron (then Socal) experimented with tank ship inerting. They installed systems on a total of 19 ships. But after 20 years they claimed there was no safety advantage no reduction in corrosion, and discontinued the effort.[1, page 208] This experience is inconsistent with everything else we know about inerting. We can only guess that the systems were not properly maintained, starting a downward spiral, which ended up with the operators deciding inerting was not worth the effort. In the mid-1970's, Chevron became a strong proponent of inerting.

[2] Boyle of Sun says "During World War II, ships equipped with the system repeatedly proved the value of inerting. Torpedoes would blow out a tank and set it afire, but the surrounding tanks remained safe and sound".[2, page 241] We do know that, in addition to the Bidwell, the Sun was torpedoed twice and survived, the Pennsylvania Sun survived a torpedoing, as did the Atlantic Sun in 1942. However, four Sun Oil tankers were sunk in World War II: the J. N. Pew (1942-02-21), hit by three torpedoes, the Mercury Sun (1942-05-18a, hit by two torpedoes, the Sunoil (1943-04-05), and the Atlantic Sun (1943-02-17). In both the last two cases, the ship was attacked twice. The Sunoil had straggled from her convoy with engine problems. She was torpedoed at 0745; again at about 1800 that evening, and it still took two more torpedoes to finish her off. The Atlantic Sun was also sailing alone. The first two torpedoes broke the ship in two, but there was no fire. The stern section floated and was reboarded by the crew who started to sail her stern first to Halifax, when she was hit by a third torpedo, three hours after the first attack.

2 No Reaction for 30 Years

Amazingly, neither tanker owners nor tanker regulators took any apparent notice of Sun's success with inerting for nearly 30 years.

There was no attempt to inert tankers during World War II, despite the fact that the US Navy was well aware of the value of inerting. The US aircraft carriers were inerted (with nitrogen). The Japanese carriers were not. Several authorities claim this was a major factor in the Pacific War. But tankers which could easily have been inerted for less than a $50,000 per ship were not. Instead gun crews were put on board which did little more than increase the casualty toll. We don't know how many tankermen would have been saved by inerting in World War II. We do know that Hocking lists 264 WW2 sinkings of allied tankers in which considerably more than 4,860 lives were lost.[6][3]

After the war, tanker explosions continued. Table 2 is a very incomplete list of post-war through 1960 casualties in which inert gas would probably have made a difference The SINCLAIR PETROLORE explosion off Brazil resulted in the largest ever oil spill at the time by a factor of two. Most likely cause was cargo leaking into the double bottom.

Table 2: Some 1945 thru 1960 Casualties where inerting probably would have helped
Based on CTX CDB Version 4.5 as of 2010-04-21T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
19480925	esso salta		?	0	lightning, explosion, sank, no details
19510420	esso greensboro	M	42	7000	fog, dance of death in Gulf of Mexico, collision, fire, 44 killed
19510420	esso suez	M	2	0	fog, dance of death in Gulf of Mexico, collision, fire, 44 killed
19581019	stanvac japan	P	19	0	tank cleaning Arabian Sea, explosion, 19 killed, cause?
19600325	mobil astral	M	4	0	explosion after load Puerto La Cruz, 4 to 23 killed, cause?
19600708	esso portsmouth	M	0	0	unloading arm failed Milford Haven, spill, fire, explosion
19601206	sinclair petrolore	M	?	60000	self-unloading OBO exploded, sank off Brazil, no details
19601214	world harmony	M		0	collision in Bosporus, three ships on fire, 52 killed, no cause
19601214	petar zoranic	M		20000	collision in Bosporus, three ships on fire, 52 killed, no cause
19601214	tarsus	M	52	0	collision in Bosporus, three ships on fire, 52 killed, no cause

One of the most dramatic of these casualties was the STANVAC JAPAN, Figure 1. She was almost certainly tank cleaning when she exploded in the Arabian Sea in October, 1958. The explosion ripped the deck off almost all the center tanks and tossed the midships house into the sea. At least 19 were killed, including everybody on the bridge. Stanvac was a joint venture between Esso and Mobil. CTX has no evidence that either reacted to the casualty in any meaningful way.

About 1960, BP, which was experiencing very rapid tank corrosion in their ships carrying high sulfur Mideast crude, became interested in inerting *as a corrosion control method*. BP visited Sun, inspected some ships and the system, and developed their own varient which closely followed the Sun design. In April, 1961, they retrofitted the British Skill with an inert gas system (IGS).[5]

Over the next three years, BP conducted an extensive series of corrosion rate tests on five ships, two of which were non-inerted controls. The numbers were somewhat clouded by teething problems, equipment malfunctions, extended periods during with the tanks were exposed to normal air, and measurement difficulties. On the British Sovereign, which had the best performing system, the average wastage rate was 0.0042 inches/year as opposed to the control ships which had average wastage rates of 0.0162 and 0.0156 inches per year respectively. During the test period, the average O2 content in the Sovereign's tanks was 5.4% when the tanks were inerted, but 8.2% when repair/inspection time were included, implying the tanks were not inerted close to 18% of the time. Overall the Sovereign results agreed roughly with BP laboratory tests which showed 0.014 in/year wastage in air and 0.005 in/year at 9% our year.[4] The relative improvement in the max wastage was higher than that for the mean, but meaningful quantitative figures were not derived.

[3] Hocking is not complete and often does not give a casualty toll, or tells us only the number of survivors. It is a safe guess that the number of fatalities in these 264 sinkings is 6,000 or more. And that doesn't count the dead in non-sinking explosions.

[4] We shall see that these numbers can be dramatically improved upon by careful operation of the system.

Figure 1: Stanvac Japan after tank cleaning explosion. 19 killed.Source: Ships Nostalgia

If the IGS had completely stopped all wastage, we would still expect the Sovereign to have a wastage rate about 1/5 that of the control ships, due to the percentage of the time her tanks were exposed to normal air. In other words, while the tanks were inerted at an average of 5.4% O2, the wastage rates were 1/12th that of the control ships.

The BP program was pushed at a leisurely pace. From 1963 on all new BP crude carriers were fitted with inert gas systems at build. The program did not extend to most existing tankers. On 8th August 1966, the 1952 built, 28,598 dwt British Crown was just finishing loading crude at Umm Said, Qatar when she exploded killing 19 and badly injuring 8. The ship was non-inerted, fitted with gauze flame screens. Ex-BP personnel familiar with the ship believe gas accumulated aft of the forward house which may have been ignited by a spark from a faulty A/C fan. Here's one quote

> The faulty aircon unit was in the officers' smokeroom at the after end of the centre castle. The room was sometimes used as the office during loading and unloading as it exited straight out at the flying bridge level. While loading tanks 5 and 6 across, gas could accumulate in this area. [John Firmin,www.shipsnostalgia.com,posted 2005-08-01]

3 VLCC's and Inerting

Aside from Sun and BP, there was little activity on inerting through the 1960's. The US Navy, Esso, and others dabbled with IGS in the late 50's and early 60's.[1] But the results were either deemed inconclusive or failures. Successful introduction of inerting requires strong direction from management, a hard push at the superintendent level, and committment by the crews. If any of these are lacking, the whole thing falls apart as soon as the first problem is encountered,

Tankers continued to explode. Table 3 is an incomplete list of 1961 through 1969 explosions and fires where IGS probably would have helped. At least 218 people were killed and 185,000 m3 of oil spilled in these casualties.

And tankers exploded in size. At the beginning of the 1960's, the largest tanker afloat was about 100,000 tons. In 1966, the first ship over 200,000 tons deadweight was delivered. Since the press had started calling the 60,000 and 80,000 tonners built in the late 1950's "supertankers". No one knew what to call these new ships. For want of imagination, they became known as *VLCC*'s (Very Large Crude Carriers)

As Table 3 shows, in the space of three weeks in December, 1969, three nearly new VLCC's had massive cargo tank explosions. In all three cases the ships were cleaning empty cargo tanks. As we have seen, tank cleaning casualties were hardly new. There had been many such fires in the past, most recently Seven Skies which killed four crew. But three such explosions in short order, two of which were Shell VLCC's, at least got Shell's attention.

Cargo tank cleaning is accomplished by machines that look like and work like enormous lawn sprinklers. These gadgets shoot a revolving high pressure jet of sea water around the tank, in theory blasting the surfaces clean of oil. Two of the tankers involved, the Marpessa and the Mactra were Shell ships. The third was the brand new Kong Haakon VII. The Marpessa, on her maiden ballast leg, sank killing two crewmen. The Mactra, Figure 2, and the Kong Haakon VII, Figure 3, had a large portion of their main decks blown away but survived.

Shell instituted a crash research program and came to the conclusion that the high speed jets of water impinging on the steel surface of the tank were creating static electricity, in somewhat the same way that rain drops in a thunderstorm do.[8] When enough static electricity builds up, it produces a spark in space that is full of hydrocarbon vapor.[5] The process is tank sized dependent and didn't make itself totally obvious until tanks grew to VLCC size.

The obvious solution was inerting. Shell started fitting inert gas systems to their large tankers. Some other VLCC owners did as well. But adoption was slow and largely confined to very large, newbuildings. There was still no movement at all on the regulatory front.

[5] The exact mechanism by which the charged mist is ignited is still a subject of controversy.

Figure 2: Mactra deck after tank cleaning explosion. Two killed.
Source: Auke Visser, supertankers.topcities.com

Table 3: Sixties Casualties where inerting probably would have helped

Based on CTX CDB Version 4.4 as of 2010-03-11T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
19610126	esso durham	P	0	0	tank cleaning explosion off Gibraltar, hole in way of No 4
19640306	bunker hill	M	5	0	explosion while tank cleaning, broke in 2, sank, 5 killed
19640325	san jacinto	Y	1	0	explosion in ballast blamed on falling magnesium anode, 1 killed
19640703	bonifaz	P	25	0	Fabiola hits Bonifaz off Spain fire, sank. Classic dance of death
19650327	nora	M	0	2800	collision with Otto N Miller, fog, nil info
19650327	otto n miller	M	0	0	collision with Otto N Miller, fog, nil info
19650523	heimvard	M	10	32000	hit Muroran jetty 'at speed', explosion, 18 killed, total loss
19650605	luisa	P	32	24000	explosion loading Iran, grounded, capsized, nil other inf
19650805	kaizo maru	P	13	0	explosion loading Saudi, prob massive spill but no info
19650923	barbaros	P	15	0	explosion discharging gasoline Izmit, nil other info
19660225	anne mildred brovi	M	0	19000	N. Sea collision with Pentland in fog, cause?, grounded, CTL
19660225	pentland	M	0	0	N. Sea collision with Pentland in fog, cause?, grounded, CTL
19660312	world liberty	M	5	0	collision with World Liberty in Red Sea, conflicting data, cause?
19660820	british crown	P	19	23000	explosion topping off at Umm Said, prob spark from A/C unit
19661211	iphigenia	M	3	0	tank explosion in ballast, no inert, 3 killed, sank
19670103	esso glasgow	P	0	600	Non-inerted T2, tank explosion loading Fawley, ship repaired,
19670122	jacob verolme	P	1	0	Ore/oiler explosion, loaded iron ore, hotwork on deck, sbt Leak?
19670322	circe	P	38	0	tank exp Med, possibly loose deck equip, broke in two, 38 lost
19680228	mandoil ii	M	11	50500	collision off Oregon in hvy fog, probable B encounter. Nil info.
19680426	assimi iii	M	5	20000	ER fire south of Singapore, sank, nil info on initial cause
19680506	islas orcadas	M	4	13000	ruptured hose loading gasoline La Plata, 3 ships sunk, spill?
19680506	fray luis beltran	M	0	0	ruptured hose loading gasoline La Plata, 3 ships sunk, spill?
19680506	cutral co	M	0	0	ruptured hose loading gasoline La Plata, 3 ships sunk, spill?
19681020	sitakund	P	3	526	tank exp in English Ch. ballast, probably pre-IG tank cleaning
19690724	silja	P	20	0	Non-inerted Silja hit by Ville de Majunga off Toulon, fire, sank
19691006	seven skies	P	4	0	non-inerted tank cleaning explosion NE Singapore
19691212	marpessa	P	2	0	non-inerted VLCC tank cleaning explosion off Dakar, sank
19691229	mactra	P	2	0	non-inerted VLCC tank cleaning explosion off Mozambique
19691230	kong haakon vii	P	0	0	non-inerted VLCC tank cleaning explosion off Liberia

Figure 3: Kong Haakon deck after tank cleaning explosion. Obvious similarity to Mactra. Source: Auke Visser, supertankers.topcities.com

4 The USCG Finally Acts

Finally, in 1974, 42 years after the BIDWELL, the United States Coast Guard required inerting, but only on crude tankers over 100,000 tons built after 1974.[6] The regulation applied only to ships trading to the United States. But this was a key impetus. Many front line owners who required the flexibility to trade to the United States started including IGS in their VLCC newbuilding specifications. Otherwise, tanker owners continued to ignore inerting.

On the evening of December 17, 1976, the non-inerted 70,630 dwt tanker SANSINENA had just finished discharging at the Union terminal in Los Angeles. As she began ballasting, tank vapors were pushed out on deck. Winds were light. At 19:38 the ship exploded midships, caught fire, and sank. Debris was scattered everywhere, cutting an on-shore cargo line which fed fuel to the fire. Nine people were killed on board. At least, 58 people were injured, many of them on shore. Over 400 boats were oiled. Millions of dollars of shoreside damage. The USCG concluded that explosive vapors had built up in the area between the deck houses, the vapor had somehow gotten into the midship house where there were plenty of possible sources of ignition, caught fire, and flashed back to the tanks. In short, a near repeat of the BRITISH CROWN. The fact that the vent piping on deck was badly corroded and holed exacerbated matters.[7] Because of the location and shoreside injuries and damage, the SANSINENA was a very high profile casualty. In 1977, the USCG required IGS on all oil tankers trading to the USA down to 20,000 deadweight tons.

Once again the regulation only applied to ships trading to the US. IMO and the Classification Societies did nothing to prevent a rash of tank explosions in the 1970's as Table 4 shows. At least 510 people died and 956,000 m3 of oil was spilled in these casualties. One of the worst of these was the E M QUEENY/CORINTHOS collision in which the non-inerted Queeny slid into the non-inerted Corinthos at very low speed, penetrating only one tank. The Corinthos had almost completed discharge at the time. But the fire from that tank quickly spread to the rest of the ship, killing 24. Ironically, the Corinthos was discharging at Marcus Hook.

Even worse was the BETELGEUSE. The BETELGEUSE exploded at 01:00 on the night of January 8th, 1979. while discharging at Bantry Bay. All aboard and at the terminal were killed, so we don't know exactly what happened. But we do know from the Irish investigation that:

1. The Betelgeuse's hull steel was in horrible condition, especially the midships permanent ballast tanks. Both the owner, Total, and the classification society, Bureau Veritas, was aware of this, but had done nothing in part because Total intended to sell the ship.[12]
2. Ten years after the MARPESSA et al this 120,000 ton ship, owned by a major oil company, was not inerted. Total tankers did not trade to the USA, so they had no need to comply with USCG regulations.

Best guess is that cargo leaking into the ballast tanks, was ignited, perhaps by the structure failing. Without inerting the fire quickly spread to the cargo tanks, which blew up, killing 50.

On the plus side, we began to see some of the benefits of inerting. The VENPET/VENOIL was a high impact collision off South Africa between two 300,000 ton tankers, one of which was loaded. Both ships were inerted. The loaded Venpet travelling at 13.5 knots hit the Venoil in ballast, also at about 13.5 knots, just forward of the bridge. The Venoil caught fire aft; which fire spilled onto the Venpet, whose forward cargo tanks were holed. Both ships were abandoned. As the ship drifted, *both fires went out.* Both ships survived. "Only" two crew were killed, The great bulk of the Venpet's cargo was saved, and a 300,000 ton plus spill was averted. Contrast this with the OSWEGO GUARDIAN/TEXANITA a somewhat similar collision in the same area. The non-inerted Texanita exploded killing 43, despite the fact that like the Venoil she was in ballast.

In July, 1980, about six months after the BETELGEUSE the ENERGY CONCENTRATION broke in two while she was discharging at Rotterdam. But unlike the Beteleguese, there was no fire, no fatalities, and nil pollution. The Energy Concentration was inerted.

[6] The regulation applied to pure tankers over 100,000 dwt and combination carriers over 50,000 dwt whose keel-laying date was after 1974-12-31.

[7] The Sansinena was Liberian flag, classed by Lloyds Register.

Table 4: 1970's Casualties where inerting probably would have helped

Based on CTX CDB Version 4.4 as of 2010-03-11T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
19701023	pacific glory	M	13	6000	Pac. Glory/Allegro in Channel, one said overtaking, one crossing
19710111	texaco caribbean	P	8	638	fog, coll w rogue vessel E.C. exploded, sank, others hit wreck
19710217	ferncastle	M	7	0	tank explosion in ballast, sank, no real cause info
19711115	elcano	M	4	0	another non-inerted tank cleaning explosion, 4 killed
19720128	golden drake	M	2	32000	explosion forward while loaded, sank, Bulkpetrol Class, cause?
19720201	v a fogg	P	39	0	T2 explosion tank cleaning off Texas, part-loaded, no IG
19720420	silver castle	M	16	0	coll w S.A. Pioneer in dense fog, no cause, lightered, sunk
19720506	esso chittagong	M	0	0	slow speed dance of death at Bangkok pilot station
19720511	tien chee	M	8	5600	collision w Royston Grange Rio Plata due to bank effect, 82 dead
19720514	golden jay	M	3	0	tank explosion, sank in ballast, probably hotwork in bad tank
19720821	texanita	M	43	0	coll w Texanita off S. Africa, Texanita explodes, sank,cause?
19720826	princess irene	P	6	0	lightning strike discharging crude Donges, not inerted, 6 killed
19721101	san nicolas	P	3	0	tank exp leaving Brindisi after discharging naptha, no inerting
19721216	bello	M	0	18000	explosion W Med in No 3 tank, prob sbt, towed in, scrapped
19721219	sea star	M	12	141100	collision Gulf Oman, one Port to Port, one stbd to stbd
19730602	esso brussels	M	13	5000	rammed NY harbor by Sea Witch whose steering gear failed
19730621	mobil pegasus	Y	0	0	non-inerted 1C exploded during ballast exchange, abt 5 hurt
19730625	philippine leader	M	6	0	tank exp in ballast off S Africa, 6 killed, no cause info
19731105	golar patricia	Y	1	5880	explosion off Canaries in tank being cleaned, sank
19740118	keytrader	P	2	2790	dance of death with Baune in lower Mississippi River
19740222	nai giovanna		8	3490	OBO, tank explosion N Pacific, tank clning?, Berge Istra, Vanga?
19740409	elias	P	13	3500	tank explosion, discharging Delaware R no inert, rust, no cause
19740809	metula	M	0	62000	grounded Str of Magellan, pilot error, no place for VLCC
19741010	tekton	M	0	600	hit by loaded OBO Queen in fog off Pt Elizabeth, sank, cause?
19750129	jakob maersk	M	6	98800	grounding?, massive ER explosion mooring Leixos, cause???
19750131	corinthos	M	23	42200	hit by E M Queeny, Marcus Hook, no IG, no twin screw, pilot error
19750131	e m queeny	M	1	0	hit by E M Queeny, Marcus Hook, no IG, no twin screw, pilot error
19750417	tosa maru	M	0	2000	hit by loaded Cactus Queen off Spore, sank, no cause info.
19750417	cactus queen	M	0	0	hit by loaded Cactus Queen off Spore, sank, no cause info.
19750815	globtik sun	M	6	1110	hit platform off Galveston, bad charts, bad plotting
19751028	kriti sun	P	0	3490	fire Singapore SBM, lightning, just after discharge, inerted?
19751229	berge istra	P	30	5000	explosion in OBO double bottom Celebes Sea, 30 of 32 killed
19760512	urquiola	M	1	111700	grnd on uncharted ledge, ordered out, grnd again, fire, sank
19761217	sansinena	P	9	47600	explosion on non-inerted deck at LA, ballasting, 9 killed
19770223	hawaiian patriot	M	1	115000	big hull crack off Hawaii, fire, broke in two, sank
19770320	claude conway	P	12	0	tank explosion (cleaning?), broke in 2 off Cape Fear
19770627	gunny	P	2	0	tank explosion discharging Sete, hull failed, inerted?
19780223	cassiopeia	P	5	0	tank fire in ballast, prob cleaning, prob no IG, but need data
19781108	feoso sun	M	30	1000	Massive explosion inspecting damage after discharge, Manila Bay
19790101	master michael		31	6500	fire, sank, 31 of 35 lost, nil info
19790108	betelgeuse	P	50	47000	bad rust in uncoated ballast tank, no inert, explosion, 50 dead
19790227	saint chris	M	1	0	OBO tank cleaning explosion, East Coast USA, 1 dead, nil info
19790228	aviles	M	12	12000	broke in two Arabian Gulf, fire, sank,
19790419	seatiger	P	2	0	explosion dsching Texas, sank, lightning, IG off for cargo survey
19790626	vera berlingieri	M	1	6000	collision in fog w Emmanuel Delmas, fire, cause?, 29 dead, sank
19790816	ioannis angelicous		4	37600	explosion just after loading Malongo SBM, sank, cargo survey?
19790901	chevron hawaii	P	3	32000	explosion Deer Park, lightning combined with no/poor inerting
19791020	talavera	M	1	0	Tank explosion in ballast, CTL, non-inerted tank cleaning?
19791027	gunvor maersk	M	0	20000	'struck submerged object' Amazon, fire, sank, need more info
19791029	berge vanga	P	40	5000	Repeat of Berge Istra, OBO dbl bottom explosion, 40 dead
19791101	burmah agate	M	32	40500	collision w Mimosa inbound Galveston Bay, 30+ dead, no detect?
19791213	energy determinati	P	1	0	explosion in slop tank Hormuz, inerting not in use, sank

5 The IMO Finally Acts

Non-inerted tank explosions continued into the early 1980's. In early 1980, we had three VLCC tank cleaning explosions within a few weeks of each other: Maria Alejandra, Mycene, and the Albahaa B.

Table 5: 1980's Non-War Casualties where inerting probably would have helped
Based on CTX CDB Version 4.4 as of 2010-03-11T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
19800223	irenes serenade		2	120000	fire lowering anchor Pylos, prob cgo in FP tank
19800311	maria alejandra	P	36	4660	massive explosions off Mauritania, tank cleaning?, 36 killed
19800403	albahaa b	P	6	4660	tank fire off Tanzania while tank cleaning, very likely bad IG
19800403	mycene	P	1	4660	tank fire off Sierra Leone, prob bad IG while tank cleaning?
19800722	energy concentrati	P	0	0	broke back dschging Rotterdam, tired CO screw up, IG worked
19800821	texaco north dakot	M	0	2860	hit new, unlighted jacket in GOM, charts not up-to-date
19801231	blossom	M	1	0	explosion off Sardinia, broke in two midships cause?
19810329	cavo cambanos	M	6	24300	fire in generator room Tarragona, fire, later scuttled, cause?
19810520	anna xyla	M	0	0	pump room, engine room fire, Jebel Dhanna, beached, no cause info
19810531	monticello victory	P	0	0	corroded bilge line/hose to cgo tank left open, ER exp. Pt Arthur
19810712	hakuyoh maru	P	7	3490	'struck by lightning' end discharge Genoa, probably no IGS?
19811210	riva i	M	2	0	Accom? fire discharging Eilat, scrapped, no other info
19820306	golden dolphin	P	9	3490	hot work on deck, tank explosion,
19821013	unirea	M	2	757	tank explosions off Bulgaria, sank, tank cleaning? inerted?
19830107	assimi	M	0	60200	ER fire, Gulf of Oman, cause uncertain, spreads to tanks, sinks
19831126	pnoc basilan	M	6	19800	'waves forced open a tank cover', ? fire off Luzon, sank
19840226	american eagle	M	8	582	exp cleaning gasoline tank GOM, static from plastic sleeve
19850408	fuji	M	2	582	tank cleaning exp, prob no IG, bow sank, stern CTL
19850526	petragen one	M	14	5880	explosion San Roque refinery Algeciras while discharging naptha
19850526	camponavia	M	12	0	explosion San Roque refinery Algeciras while discharging naptha
19850914	sinoda	P	1	582	explosion while gas-freeing off Japan
19860303	galini	Y	5	0	headed for repairs, tnk clning, two explosions, 5 killed, CTL
19860507	alexandros f	P	0	0	OBO loaded iron ore, No 3 hold explodes, sank, crew rescued
19860604	southern cross	M	3	9320	tank explosion while loading gasoil Skikda, cause? inerted?
19861001	angel	M	0	0	exoceted by Iraqis in ballast, hit fwd, fire, repaired
19870623	vitoria	M	6	20	collision w Vitoria in Seine 'damage to helm'
19880422	athenian venture	M	29	40000	fire off Newfoundland, broke in 2, hull failure?
19880831	fiona		1	0	exp,static chg from stm leak, no IG, set off by tape, Long Is.
19890314	maasgusar	P	23	0	Explosion in ER, spread to methanol cargo, broke in two sank

At this point, the underwriters at Lloyds finally stepped in and imposed a surcharge of 0.1% per year on VLCC's not fitted with IGS.[7, page 158] Assuming a $20,000,000 dollar hull value, the $20,000 per year saving would pay for the system in two or three years. By 1983, almost all big tankers were fitted with IGS.

This was fortunate for in late 1982, the Iran/Iraq War started and tankers were caught in the middle. Over the next six years, there were at least 346 attacks on defenseless tankers in the Persian Gulf. At least 198 tanker men were killed. But the toll would have been far worse without inerting. Only 4 tankers over 5,000 dwt were actually sunk, and in 3 of these sinkings, there's a good chance the ship was not inerted. In 286 of the 346 attacks, the tanker survived to trade again.[8] Here's a particularly dramatic example of the value of inerting from Newton.[11, page 118]

> A typical attack on a tanker is recounted by Captain Bruce Ewen, master at the time of the 412,000 dwt World Petrobras which was bombed by Iraqi jets on 22 December 1987. At the time the tanker was providing floating storage off Iran's Larak Island in the northern part of the Strait of Hormuz. Two Russian made 500 lb bombs with parachute drogues attached dropped onto the maindeck during the attack by Mirage jets, which also hit two other tankers off the island.
>
> World Petrobras was at the time transferring oil from one tanker, Free Enterprise, into another, British Respect. "When the bombs struck," Ewen recalls, "the rubber hoses attaching us to the British Respect were set afire and a large amount of shrapnel from our deck fittings blew through the side of the British Respect. *Since we were both inerted and had our inert gas plants running, an explosion was avoided.* [Emphasis mine.] However, we needed to get British Respect away from us so we could get firefighting tugs alongside."
>
> "We cut her aft ropes and her master went ahead on the engines and ran the forward ropes off the reels. When she parted the hoses, a large amount of oil was dumped into the water which

[8] These statistics were extracted from Navias and Hooton.[10] However, I am responsible for the numbers.

caused a large fire and set the rubber fenders ablaze. Although this rendered our lifeboat and the liferaft on the port side beyond use, the current was fairly quick so the danger passed in a fairly short time."

The World Petrobras resumed operations 42 hours later.

There are major differences between the World War II and Gulf War attacks, mainly the size of the ships. But still the differences are striking. In the one case, we know of 264 casualties which killed about 5000 crew; in the other, we know of 346 casualties which killed about 200.[9]

During this period, the International Maritime Organization (IMO) finally made an appearance. IMO rules required IGS on all new oil tankers above 20,000 deadweight delivered after May 1982. By May, 1985, these rules were extended to existing tankers. Chemical tankers were exempted. as were product carriers under 40,000 dwt which were not fitted with high capacity tank washing machines, Chemical tankers were exempted on the grounds that the inert gas would contaminate chemical cargos. No rationale was offered for the the 20,000 dwt lower limit.

For the most part, these IMO rules merely ratified what had already happened. In any event, they were about 50 years too late. However, the IMO Regs did include one important newish safety factor, and that was a requirement for *a closed ullage system*. This simple, cheap rule allowed cargo surveys to take place without opening up the tank and destroying the inert atmosphere. The CTX database contains 8 casualties involving 24 deaths and 44,000 m3 of spilllage, where we believe opening up the tanks for survey may have been a causal factor. IGS combined with closed ullage and modern tank cleaning machines would have prevented the first Bidwell explosion.

Table 6: Casualties where opening tanks for cargo survey was probably a factor

Date	Ship	SVY	Dead	Vol(m3)	Synopsis
19720826	princess irene	M	6	0	lightning strike discharging crude Donges, not inerted, 6 killed
19751028	kriti sun	M	0	3490	fire Singapore SBM, lightning, just after discharge, inerted?
19790419	seatiger	Y	2	0	explosion dsching Texas, sank, lightning, IG off for cargo survey
19790816	ioannis angelicous	P	4	37600	explosion just after loading Malongo SBM, sank, cargo survey?
19810712	hakuyoh maru	P	7	3490	'struck by lightning' end discharge Genoa, probably no IGS?
19880831	fiona	Y	1	0	exp,static chg from stm leak, no IG, set off by tape, Long Is.
20010117	emilia theresa	Y	0	0	bad survey benzene fire after loading Santa Clara Brazil
20030619	efxinos	M	4	0	explosion at end of lightering off Fujairah, cause ?

[9] Moore lists 145 attacks on American flag tankers in World War II. 107 of these were sinkings. Of the 38 that were not, 5 were Sun Oil tankers.[9]

6 The 1990's: most of the fleet finally inerted

The value of inerting really shows up in our rather short list of tanker explosions in the Nineties.

Table 7: 1990's Non-War Casualties where inerting probably would have helped
Based on CTX CDB Version 4.4 as of 2010-03-11T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
19910411	haven	M	5	16470	tank fire anch off Genoa, prob leak into SBT, 2C
19920418	world hitachi zose	P	1	900	collision with bulk carrier off Morocco, holed, fire 1S, cause?
19920420	seastar	P	2	0	tank vented during repair work forward, explosion in 3C,IG?,
19920919	nagasaki spirit	P	26	14100	piracy, NUC collision w Ocean Blessing N end of Malacca, 51 dead
19930925	altair	P	3	0	explosion during manual tank cleaning, tank not inerted
19940313	nassia	P	18	23500	BC Shipbroker black out, no rudder, coll Bosporus, massive exp
19981029	champion trader	M	1	12	hotwork abv bfo tank, 1 dead, small BFO spill, 3000 bbl palm oil

The Haven probably involved cargo leaking into into a non-inerted pemanent ballast tank, combined with poor inerting.

The Nagasaki Spirit was actually a victory for inerting. The container ship Ocean Blessing was captured by pirates at the west end of the Malacca Straits. The crew either locked themselves in or were locked in. The ship proceeded at high speed eastbound, apparently out of control. At 21 knots, she T-boned the 95,987 dwt loaded tanker, Nagasaki Spirit, on the port side aft. The breached tanks on the Nagaski Spirit caught fire and the fire spread to the non-inerted Ocean Blessing which was engulfed in flames. The entire 25 man crew of the Blessing and probably some of the pirates were fried. These deaths are not included in Table 7 since they could not have been avoided by controlling the fire on the tanker. But on the inerted Nagasaki Spirit, the fire was confined to the port side aft. It appears the crew successfully abandoned ship in the starboard lifeboat; but were then murdered for their wallets and watches. The Nagasaki Spirit survived and was repaired.

The Altair is a bit of an inigma. She blew up tank-cleaning. Her last cargo was naptha. We know she was not inerted at the time; but we are not sure whether she was fitted with an IG system. With a deadweight of 20,848 tons, she was slightly above the arbitrary 20,000 dwt limit; but may have been exempted from inerting if her tank washing machines were small enough, What we do know is that she was detained two months earlier by the Canadian Coast Guard in Victoria. The Canadians found the ship in very poor condition. In any event, inerting is useless unless it is used.

We don't know why the death toll in the Nassia/BC Shipbroker collision was so high. Both ships were Cypriot flag. The flag state investigation, if there was one, has not been made public. We do know that the BC Shipbroker had a black out in the Bosporus, lost steering, and turned into the Nassia rupturing at least 2 forward port cargo tanks. The fire immediately spread to the Shipbroker, killing 24 of her crew.[10] The fire also apparently spread aft on the Nassia, killing 18 of her crew, but most of the cargo was unharmed. Not much of a victory for inerting.

But the overall performance in the Nineties when compared to the Eighties, when the fleet was partly inerted, and especially to the Seventies, when the fleet was largely uninerted, is a very strong testament to the efficacy of inerting.

7 2000 to the present

So far in the 21st century almost all tanker explosions have involved ships less than 20,000 dwt or parcel tankers which were exempted because they can carry chemical other than petroleum.

The exceptions are the Limburg, Heng San the Efxinos and the Northsea

The Limburg is actually a victory for inerting. This 299,364 dwt VLCC was bombed by Jihadists off Yemen while partially loaded. Thanks to her inerting, the fire was contained and the ship survived.

The Heng San, a 24 year old small VLCC, had extra people on board for tank cleaning, and maybe tank repairing. The ship was ventilating 4C, which apparently still had a little cargo in it

[10] These deaths are not included in Table 7.

Table 8: 2000-2010 Casualties where inerting probably would have helped

Based on CTX CDB Version 4.4 as of 2010-03-11T08:25:19

Date	Ship	IGS	Dead	Vol(m3)	Synopsis
20010115	p harmony		9	500	unsafe charter forced unsafe purging, tnk explosion, no IG, sank
20010611	heng san		7	0	tank explosion while purging Arabian Sea, 7 killed, sinks?
20021006	limburg	M	1	0	attacked while approaching Yemen SBM to top off
20030613	chassiron		1	0	tank explosion during tank cleaning, not inerted, one killed
20030619	efxinos		4	0	explosion at end of lightering off Fujairah, cause ?
20040101	panam serena	P	0	0	dschging benzene Porto Torres, no inert, fire, 2 killed
20040228	bow mariner	P	21	12600	non-inert tank cleaning, explosion off Virginia, sank
20040404	ncc mekka	P	2	0	washing non-inerted tank off Brazil, fire, two killed
20041115	vicuna	P	6	5000	no inert?, tank explosion discharging methanol Paranagua, sank
20041215	sunny jewel		3	0	no IGS, poor tank purging, explosion while tank clning, 3 killed
20070529	northsea	M	7	0	31 yr old SH, claimed geg-oil tanker, after lightering Nigeria

with steam driven fans and long ducts, when the tank exploded. The Singapore flag state reported that the inert gas system was not operating, but does not say why. In short, the Heng San proved the obvious; IGS can't do any good if it's not used.

The 57,372 dwt Efxinos exploded after discharging a cargo into a bigger ship off Fujairah. The flag state (Malta) report is secret, so we don't know what happened. Despite the closed ullage system requirement, she may have opened her tanks for post-discharge cargo survey.

The Northsea is a wild one. This 32,290 dwt tanker exploded killing seven, just after reverse lightering off Nigeria, allegedly struck by lightning. (There is no economic reason for reverse lightering in this area.) The ship was a 31 year old, pre-Marpol single hull trading oil way past the single hull deadline. She is listed as a vegetable oil tanker, which she clearly wasn't. She was delisted by Lloyds in 2005; there is no record of any replacement Class. At the same time she shifted to Cambodian flag. Given all the other "irregularities", we have no idea if the Northsea was inerted. Even if the lightning story is true, lightning should have nil effect on a properly inerted tanker. I can only conclude that 73 years after the Bidwell, this ship was effectively un-inerted.

In any event, with "only" four big tanker explosions, regulatory attention turned to the arbitary 20,000 dwt limit and the exemption of chemical tankers. The main motivation was the Chassiron, Panam Serena, and Bow Mariner casualties.

The 9,995 dwt chemical tanker Chassiron was exempted from inerting. She was tank cleaning after discharging a cargo of heating oil (1 P&S), gas oil (2,3,4,5 P&S), and 98 octane gasoline (6 P&S). Just after tank cleaning started in the 6's, a whistling sound was heard, followed by an explosion in 6S, then 6P exploded, and then 5P. One crewman was killed. The investigation concluded that oxygen had entered all the tanks during discharge and opening the tanks for cargo survey, resulting in a highly explosive atmosphere in at least the 6 across tanks. The source of ignition could not be determined with certainty but most likely was the in-tank cargo pump. The investigators pointed out that the atmosphere in 6S would have required only a few microjoules of energy to ignite.

Six months later, the non-inerted 7450 dwt Sun Venus exploded in the Inland Sea, killing two. She was cleaning tanks after discharging benzene and alcohol.

A year later, the non-inerted 6880 dwt Sunny Jewel suffered a somewhat similar tank cleaning explosion off Japan, killing 3 crew members and sinking the ship.

The 10,047 dwt Panam Serena was discharging benzene at Porto Torres. At 11:55, there was the first of a series of four explosions killing two. The time between explosions was approximately one minute. The investigators were unable to determine the ignition source but it is clear that an explosive atmosphere prvailed in the tanks and possibly on deck. Like the Chassiron, the Panam Serena was fitted with deep well pumps inside each cargo tanks. These could have been the source of ignition. The Panam Serena was exempt from inerting.

The Bow Mariner was a 39,891 dwt chemical tanker which was carrying ethanol when she exploded and sank off Virginia, killing 21. She had part-discharged MTBE in New York, and the 22 empty tanks had been opened on the Captain's orders for cleaning. Despite the fact that she was exempt from inerting because she was not carrying oil, she was fitted with an IGS. But it was not being used, which was both legal and standard operating procedure on this ship. The

USCG determined that the atmosphere in the opened tanks or on deck was explosive; but could not pinpoint the source of ignition. It might have been simply a spark from the stack, or more likely caused by the crew lowering air driven pumps into the gas dangerous space, using Scuba gear! There were two main explosions less than two minutes apart, each of which was actually a rapid series of explosions, representing individual tank blowing up. The investigating USCG officer recommended that inerting be made mandatory for chemical carriers. But the Commandant refused to do this claiming the IG might contaminate chemical cargos.

Two months later the 37,272 dwt chemical tanker NCC MEKKA had a somehwat similar casualty off Brazil. The ship had just part-discharged paraffinic solvent in Santos and was proceeding to the USA with the remaining alcohol cargo. She had started tank cleaning the newly emptied tanks. The ship was fitted with IGS, but like the Bow Mariner it was not being used since the cargoes were not deemed to be oil. This despite the fact that the petroleum based solvent had a flash point of -40C! It is believed that friction in the tank cleaning machine was the source of ignition. The crew did a great job of responding to the fire, saving the ship. Two crew were killed.

In 2009, at IMO Norway and other argued that there was no rational for either the deadweight limit nor the exemption of chemical tankers. Not only do chemical tankers often carry volatile petroleum products (see CHASSIRON and PANAM SERENA); but some of the other chemicals they carry are even more flammable than oil (see NCC MEKKA).

The argument that inert gas will contaminate chemical cargoes is easily countered. CO_2 is far less reactive than O_2, so the concern is water, sulfur and particulate matter. All three can be reduced to ambient levels and below by slight modifications to the IG system. Exxon and others did it with sub-cooling.[1, page 196] MSTS did it with electrostatic precipitators.[1, page 210] Hellespont did it with double scrubbing. See Appendix A. These modifications add 20% or less to the cost of an inert gas system. In the 1950's, Sun Oil demonstrated to the US Navy that JP-4 jet fuel which has very strict specs could be carried in inerted tanks without these modifications.[2, page 240] The contamination argument is simply a stalling device.

Norway and its allies argued that all cargoes with a low flash point represented the same hazard and should be treated in the same manner. However, Norway's argument was undermined by two Formal Safety Assessments (FSA's) which concluded the cost of implementing inerting to these ships were more than the dollar benefits of the lives and ships saved. One of these FSA's was done by Norway.

In early 2009, the IMO Sub-committee on Fire Protection was deadlocked on the issue, and extended the target data for new requirements to 2011. Seventy-eight years after the BIDWELL, tankers below 20,000 dwt or carrying chemicals are not required to be inerted. The BIDWELL had a deadweight of 10,950 tons.

8 May They Rest in Peace

Table 9 summarizes the CTX CDB non-War tanker casualties in which IGS would probably have helped by period. We know this table is terribly incomplete prior to 1960 and probably badly incomplete in the Sixties. It should be reasonably complete for major fires from 1970 on.

Looking at Table 9, it is hard to avoid the conclusion that, if the industry had responded as decisively as Sun Oil did in 1932, at least several hundred, perhaps as many as 500 fiery deaths, would have been avoided. And that does not include the potential for drastically decreasing the 5000 or so allied tankermen killed in World War II. To put it another way, without inerting we would probably be killing 250 more tanker crew per decade.

The obvious question is: why was the industry so slow to adopt such an obvious, effective, safety measure which probably pays for itself in reduction of tank corrosion? Why 68 years after the BIDWELL are we arguing whether tankers below 20,000 dwt should be inerted?

The equally obvious answer is that tanker owners with a few notable exceptions could not be bothered. A tanker owner rarely suffers any loss when one of his ships blows up. His P&I insurance pays off the dead crew's family, in most past cases a few thousand dollars per head. His hull

Table 9: Summary of non-War casualties where inerting probably would have helped

Period	Killed	Spilled(m3)
Pre-WW 11	88	???
1945 thru 1960	119	87,000
1961 thru 1969	218	185,426
1970 thru 1979	513	956,098
1980 thru 1989	278	305,843
1990 thru 1999	105	54,982
2000 thru 2010	63	18,100

insurance covers the loss of the ship. In many cases, the insured value is more than the market value and the owner comes out ahead.

If the owners don't care, the tanker regulatory process which is based on the Flag State and the Classification Society, won't care.[11] Both Flag States and Classification Societies must compete for owners. They are in no position to impose requirements that their customers deem unnecessary.

The International Maritime Organization is basically a collective of flag states. IMO voting and bill paying is based on the size of each member's fleet. The flag states pay IMO's bills, so the big flags of convenience are the real power at the IMO. IMO's job is to impose as little real regulation on ship owners as public opinion will allow.

Recently, the owner/flag state/class trinity has developed a new weapon to forestall meaningful regulation. It's called Formal Safety Assessment. All proposed IMO regulation is supposed to be evaluated by Formal Safety Assessment (FSA). FSA values a life saved at $3,000,000. Let's suppose the world's tanker fleet was currently not inerted. We propose to impose inerting on all the 5300 tankers over 10,000 dwt tons world-wide. To do this will cost on average roughly $400,000 per ship or a bit over 2.1 billion dollars for the fleet as a whole. Assume a ship life of 20 years. According to FSA, to justify this expenditure, we need to save 700 lives over the next two decades. But Table 9 indicates we would have difficulty arguing for a saving of more than 500 lives over that period.[12] FSA claims that the most important tanker safety measure of all time is not cost-effective, and should not have been imposed.

With reasoning like this, perhaps the strange regulatory history of tank inerting is not so strange afterall.

[11] The Classification Societies have played absolutely no role in this tale, other than to approve badly corroded steel.

[12] I've conveniently forgotten about the reduction in corrosion and the value in war, but a skilled FSA practitioner would have little difficulty shooting down such speculative claims. See Formal Safety Assessment in Wonderland for a more detailed critique of FSA.

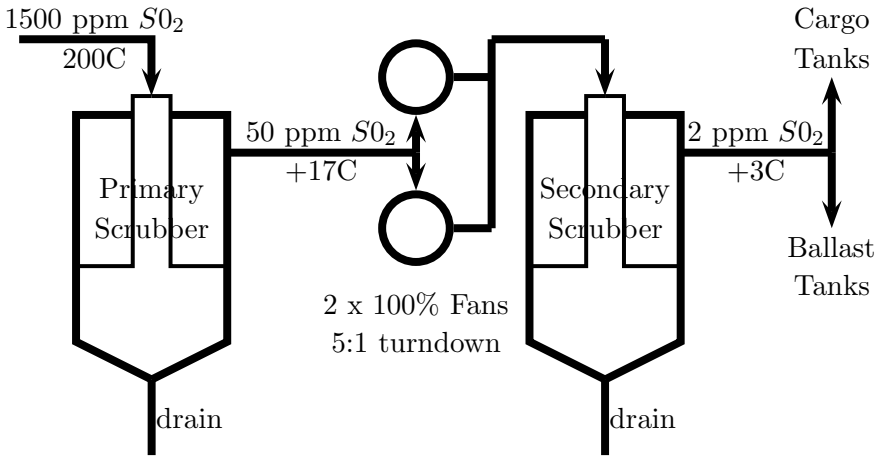
Appendix A. Ballast Tank Inerting

In the 1990's at least two tanker owners, Tankship Transport and Hellespont Shipping, began extending tank inerting to segregated ballast tanks under my direction. The motive was corrosion control. Our VLCC's and ULCC's were built in the mid-1970. The ballast tank coatings on these 15 year old ships was breaking down badly, especially in the top of the tanks. The idea was that by inerting we could obtain the same corrosion control benefits we had seen in the uncoated cargo tanks, some of which were also used for ballast.

The problem was sulfur. Tanker fuel, which is the dregs of the refining process, generally contains 3 to 4 percent sulfur. This means the stack gas coming out of the boilers contains 1500 to 2000 ppm sulfur dioxide. A good scrubber, properly maintained and operated, will cool the stack gas from about 200C to about 17C above the seawater temperature, condensing much of the water vapor in the boiler exhaust. Much of the SO_2 dissolves into the condensed water which is drained out of the bottom of the scrubber and discharged overboard. This process will remove 95 to 97% of the sulfur. The resulting gas still contains 50 to 100 ppm SO_2. It is smoky, smells of sulfur, and it still generates sulfur related corrosion, which can be seen in the IGS piping and in the cargo tanks near the inert gas inlets.

We found that by installing a second scrubber in series with the first, we could removed 95% of the remaining sulfur reducing the SO_2 content to less than 2 ppm at full load on the inert gas fans. At deballast volumes which are typically one-fifth cargo discharge rates, the sulphur content drops down to 0.2 to 0.3 ppm. You can get more than this on a winter day in New York city with an inversion. The double scrubbed stack gas is clear as a bell and has no smell. The reason why the second scrubber is so effective is that it reduces the stack gas temperature from about 17C above seawater to only 2 or 3C above seawater as shown in Figure 4. This condenses a great deal of water vapor in the stack gas. which in turn pulls out most of the remaining sulfur.

Figure 4: Double Scrubbing Schematic



The first such system was installed on Tankship's Empress des Mer in 1993. This was so successful it was quickly followed by Hellespont Shipping's installing the system on seven Ultra Large Crude Carriers (ULCC's) ranging from 320,00 to 420,000 dwt. When we did this, I had the crew purposely scrape holes in the coating in about 240 spots in one of the ballast tanks, and carefully measure the steel thickness at each of these spots. Fourteen months later we went back into this tank and remeasured these spots.

There was no wastage.[13] You did not need the thickness gauge to tell you that. The 1 to 2 cm diameter bare spots were like new except that they were covered with a very thin black film.

[13] The actual measured mean wastage was 0.009 millimeters, but this was clearly measurement noise. The standard deviation of the measurements was 0.113 millimeters, ten times that of the mean.

There was no scale and no evidence of the 15 year old coating being lifted at the edges of the bare spots. The tank was well-anoded so there was plenty of white calcareous deposits in the tank from the ballast legs.[14] But what was really interesting was there was no red or brown anywhere in the tank. At the top of the tank, where the coating had broken down earlier we had had some leafing corrosion, layers of red-brown rust that typically forms in corners. But now the leaves had turned black. I broke off one of the leaves and sent it to a lab. It was almost all magnetite, Fe_3O_4.

Corrosion proceeds from iron to magnetite, Fe_3O_4, to ferric oxide Fe_2O_3, better known as rust. The inerting had reversed this process. ***We had created reducing conditions in the tank.*** There will be no rust in such a tank.

In order to obtain these results, it is essential that no oxygen be allowed into the tanks. All inerted tanks must be fitted with *P/V valves*. These valves release if the pressure or the vacuum in the tank becomes too large to protect the structure. During the day, the tank contents heat up and expand. If the increase in pressure in the tank exceeds the release point of the P/V valves, some of the tank contents will be released into the atmosphere. In the night, when the tank cools outside air will be sucked into replace the released gas introducing oxygen into the tank. This is called *tank breathing*. Need BP citation

Tank breathing can be controlled by:

1. Painting the decks white. With white decks, the P/V valve release points will almost never be reached.
2. Continuously monitoring the pressure in the IGS system and turning on the blowers as soon as the pressure in the tank gets too close to ambient. Our rule was: if the pressure dropped below 0.05 bar gage, then the inert gas must be topped off at the next 0200 local. If the pressure dropped below 0.02 bar gage, the the IG is topped off immediately. For motor ships, the will require an independent IG generator.
3. Carefully maintaining the P/V valves, which have a tendency to leak. Leakage will expose itself in the pressure readings, and must be addressed promptly. A prerequisite here is stainless steel seat rings.

It is also important that the tank vents be located at the highest point of the tank, taking account of trim, to prevent build up of high O2 pockets in the top of the tank.

In 2001/2002 Hellespont built four double hull ULCC's which followed all these rules. The underdeck portion of the cargo tanks was uncoated. When the first of these ships was delivered, some 200 spots on the deck were marked and the steel thickness carefully measured. Two years later, just before the ships were sold, we could measure no change in thickness. Nor was there any visual sign of wastage in the underdeck steel. Bare steel coupons placed in the top of the ballast tanks, also showed no sign of wastage.

An intriguing variant or addition to double scrubbing is dehumification of the flue gas. The easiest way to do this is by cooling. In the early 60's Exxon (then Esso) fitted two ships with IG systems which had a cooling section in the top of the scubber.[1, page 196] This section was a simple fin tube coil fed by chilled (5C) water from the ships' air conditioning system. With this modification, Exxon was able to reduce the outlet gas temperature from 27C to 10C, roughly the same reduction Hellespont achieved with double scrubbing. Exxon found that this reduction in temperature reduced the water vapor content in the inert gas by a factor of four.

It is an open question whether double scrubbing or cooling is the best way to go to improving the quality of the inert gas. Both will work. My own view is that they should be combined which will result in a truly dry, clean inert gas being injected into the tanks, a gas that not even the pickiest chemical tanker operator can object to.

[14] Inert gas will not do anything for sea-water corrosion of the steel that is submerged during the ballast legs. This must be handled by anodes. Givn proper anoding, more electrons are pushed into the steel than are released by the corrosion process. This can be measured by a voltmeter, and also shows up in white calcareous deposits wherever the coating has broken down.[4, page 306-307]

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